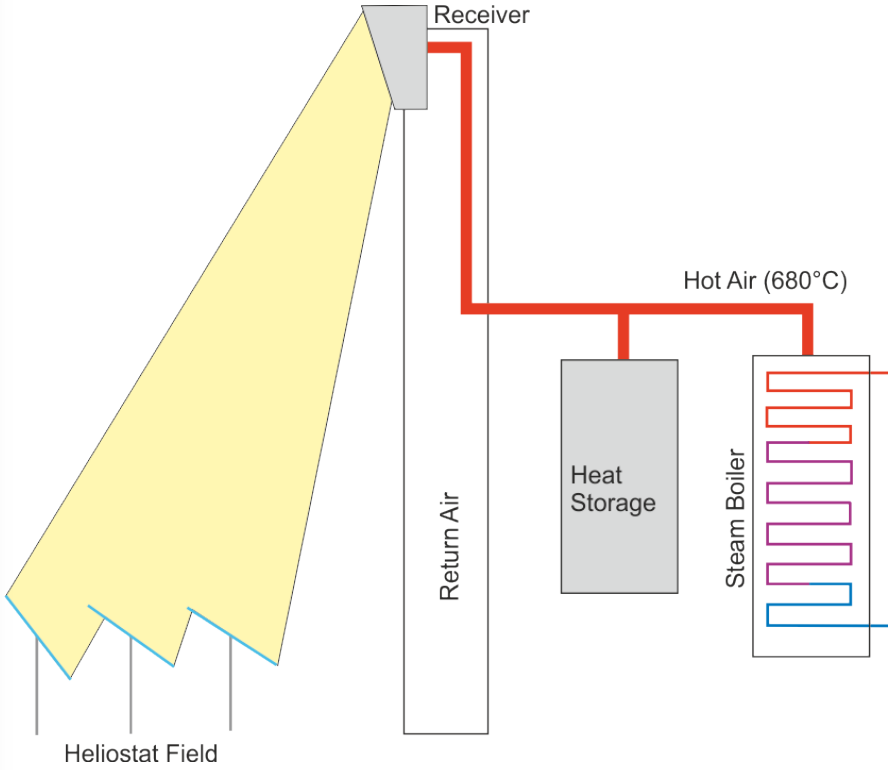
Development of a measurement technique to determine the air return ratio of open volumetric air receivers with recirculation

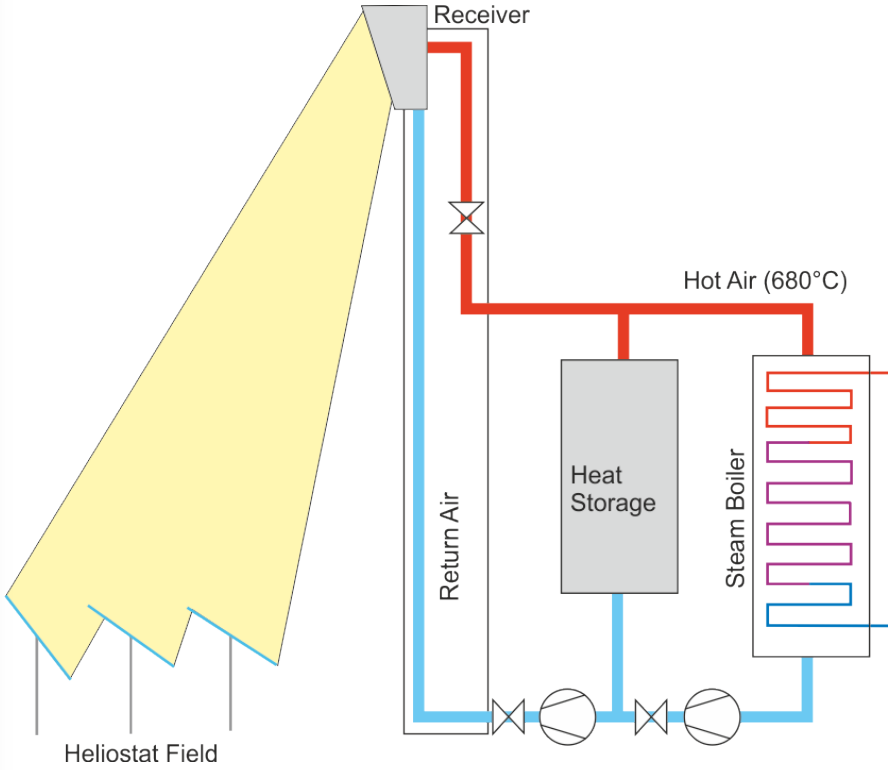
Arne Tiddens

DLR - Jülich

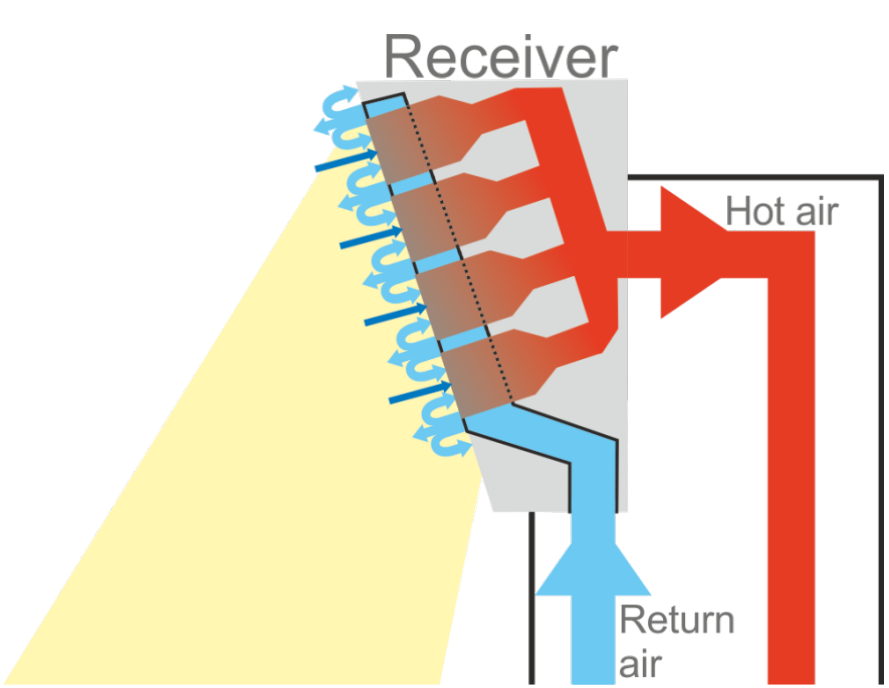
Open volumetric air receiver with recirculation

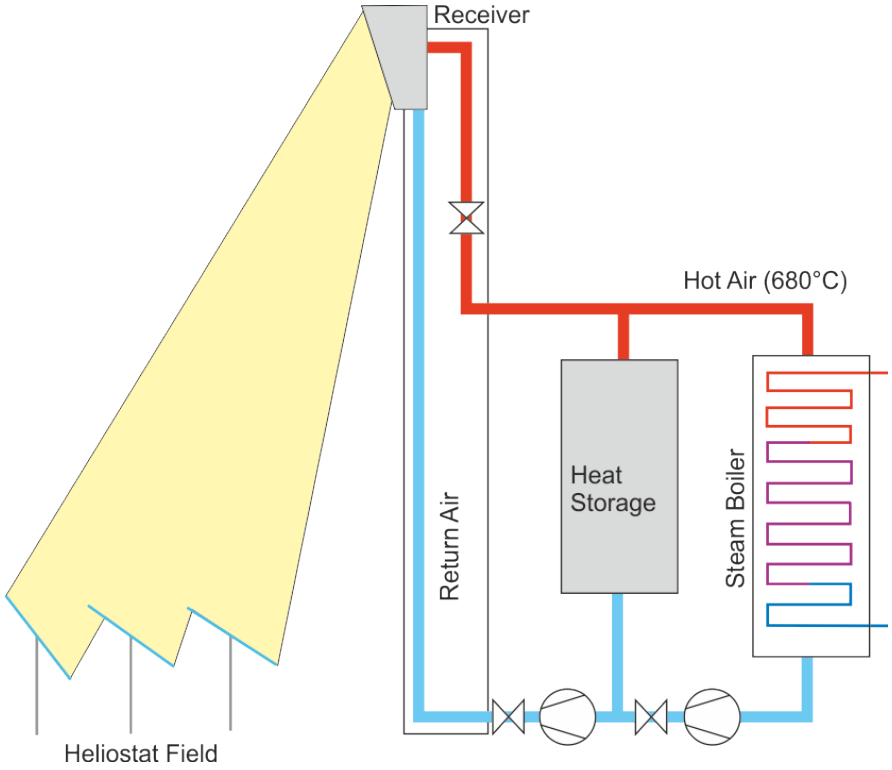


Open volumetric air receiver with recirculation

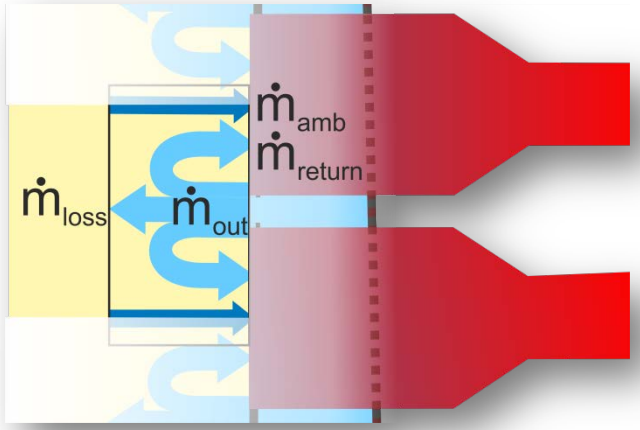


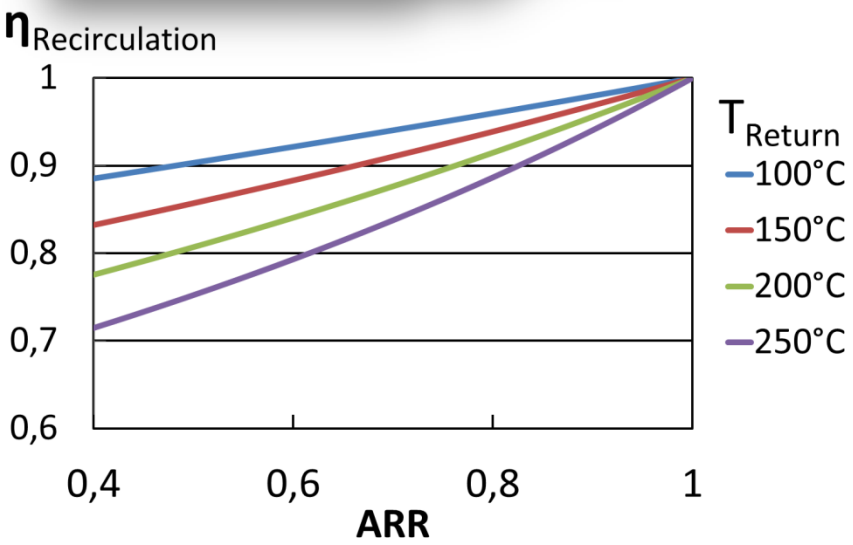
Open volumetric air receiver with recirculation





Air Return Ratio (ARR)





- The Air Return Ratio (ARR)

$$\mathrm{ARR} = \frac{\dot{m}_{\mathrm{return}}}{\dot{m}_{\mathrm{out}}}$$

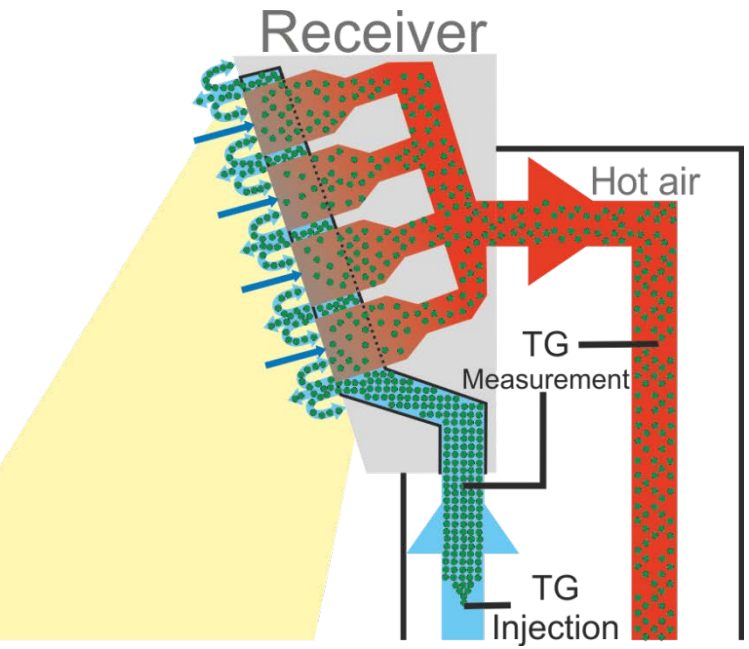
  - Influences the total efficiency
  - Depends on environmental and operational conditions
  - Can be improved

  -> has to be measured

→ **Development of measurement technique**

→ **Application at Solar Tower Jülich**

Tracer Gas



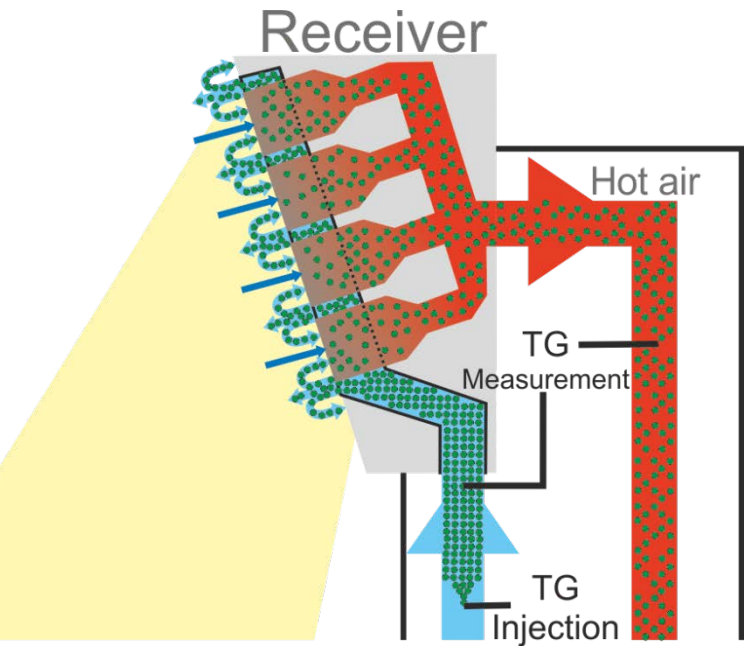
Difficult measurement: Open system, high temperatures, high air mass flows

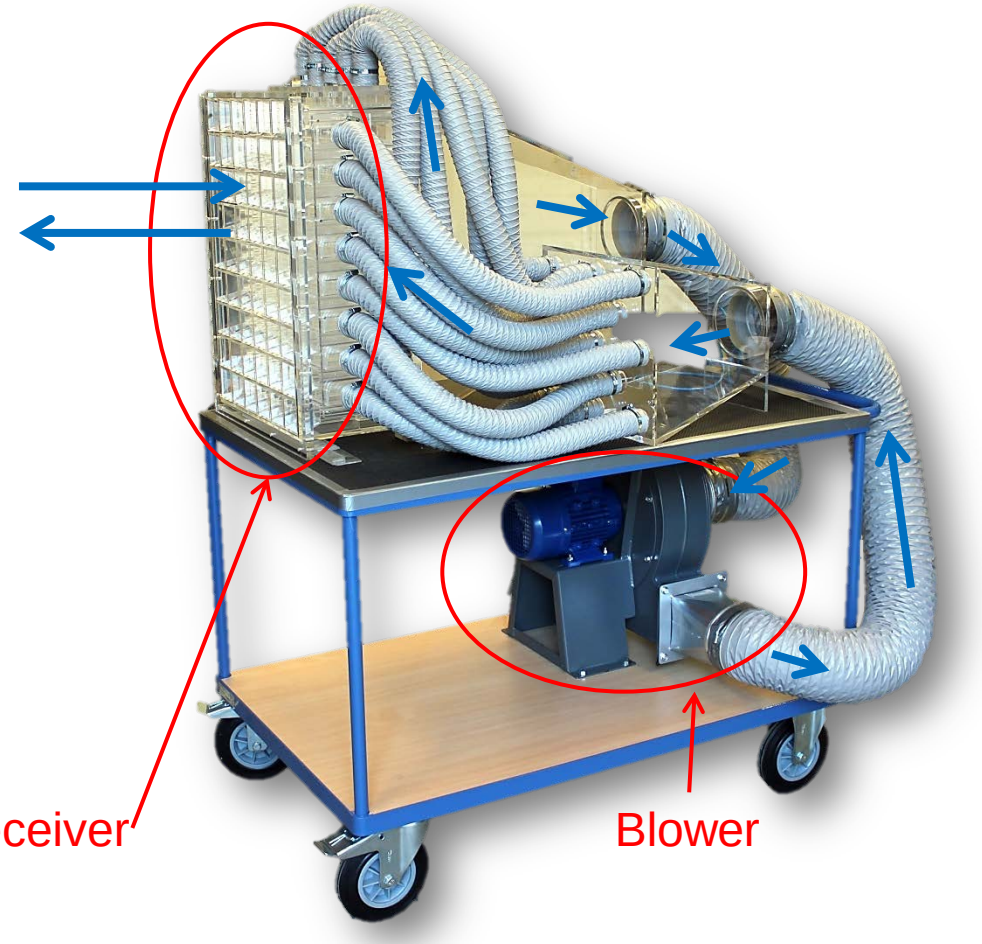
- Energy balance – only very rough estimate
  - o HiTRec-II 200-kWth (Hoffschmidt et al.,2003)
  - o SolAir 3MWth (Téllez et al., 2004)
  - o CFD - verified with HiTRec-II (Marcos et al., 2004)

- Tracer gas
  - Easily detectable gas is added - Helium
  - Concentrations are measured before and after the receiver

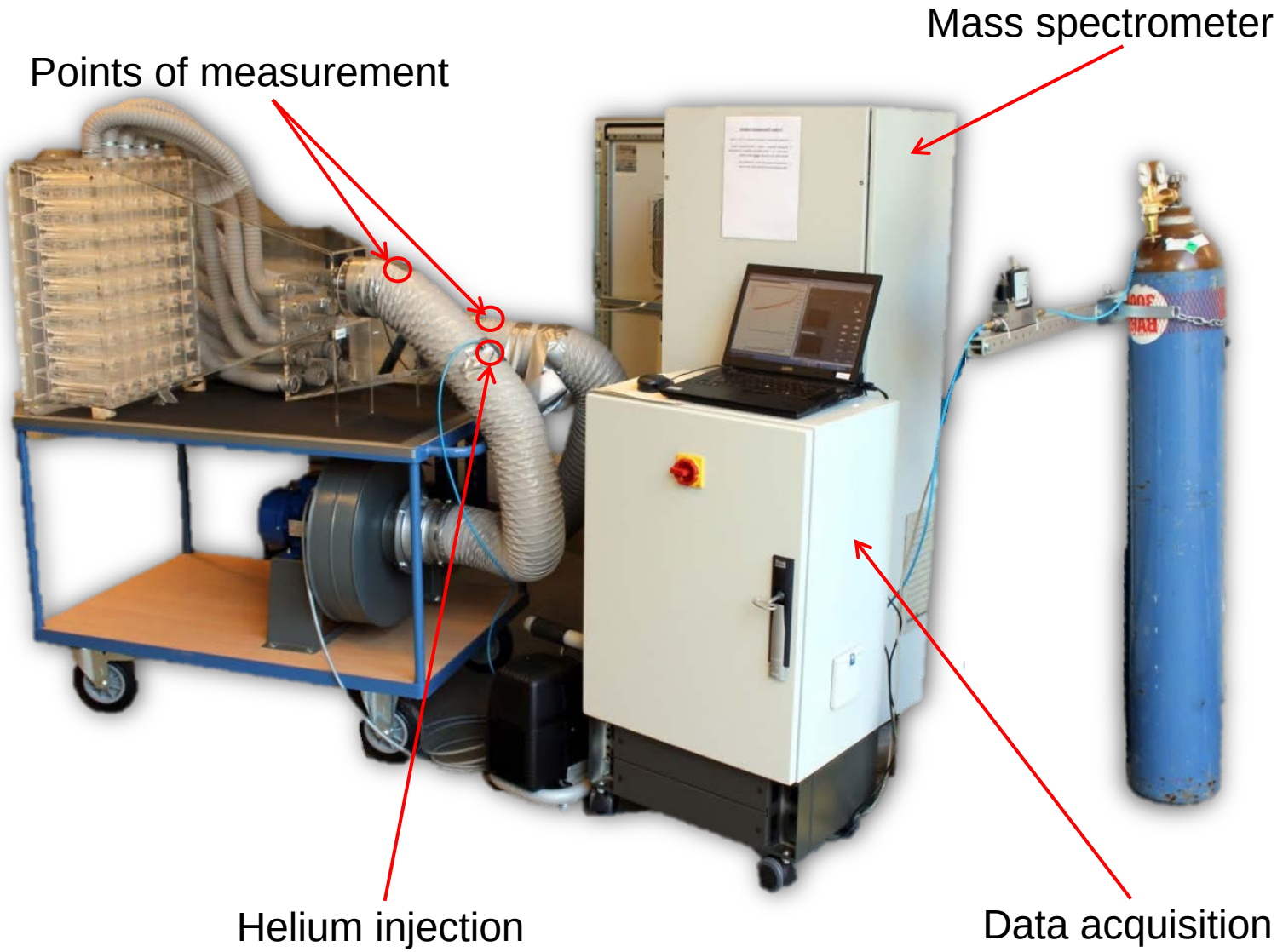
$$\mathrm{ARR} = \frac{c_{\mathrm{after}}}{c_{\mathrm{before}}}$$

Receiver model in Jülich

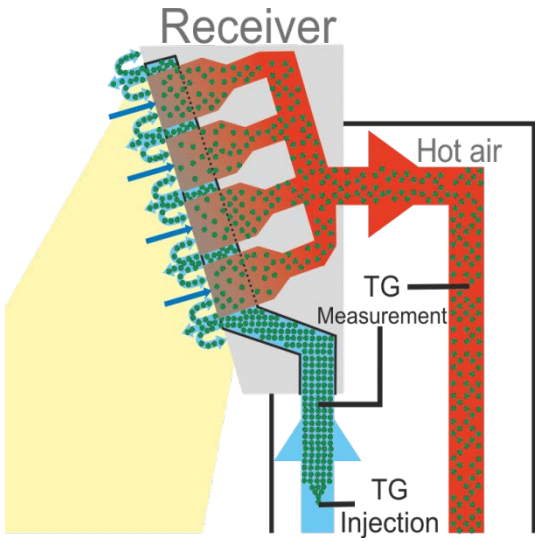




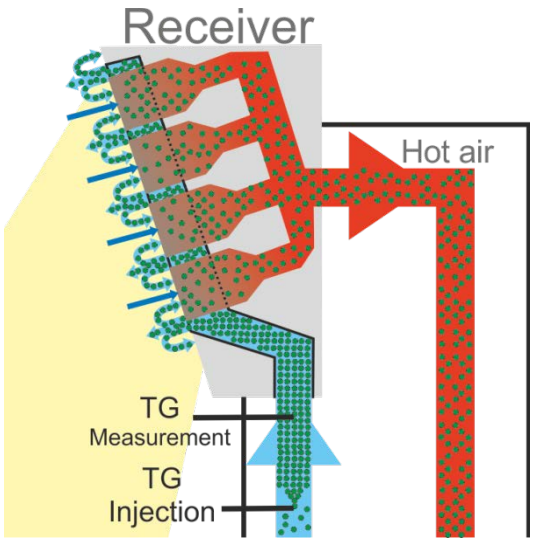
Receiver model in Jülich



Method of measurement – overview

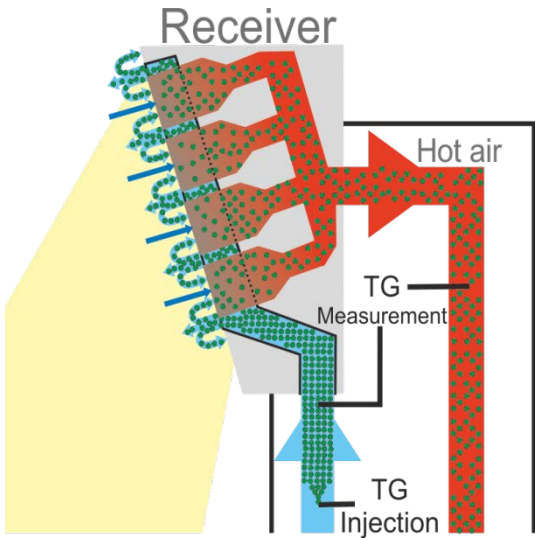


Static measurement



Dynamic measurement

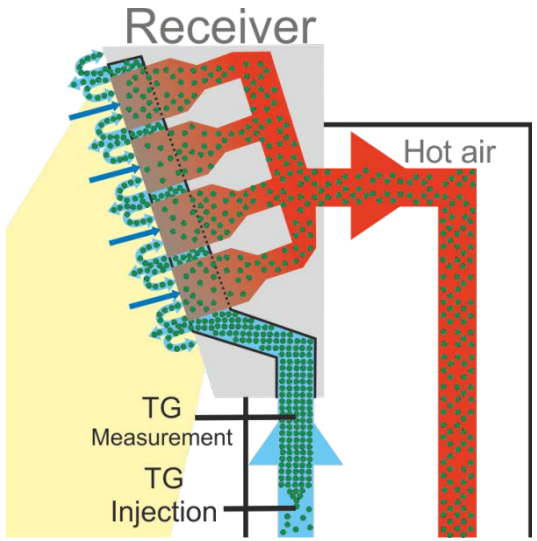
Method of measurement – overview



Static measurement

2 points of measurement

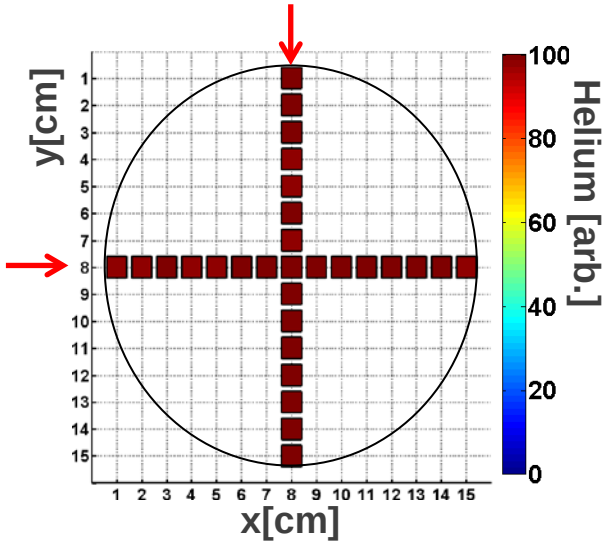
$$\mathrm{ARR} = \frac{c_{\mathrm{after}}}{c_{\mathrm{before}}}$$

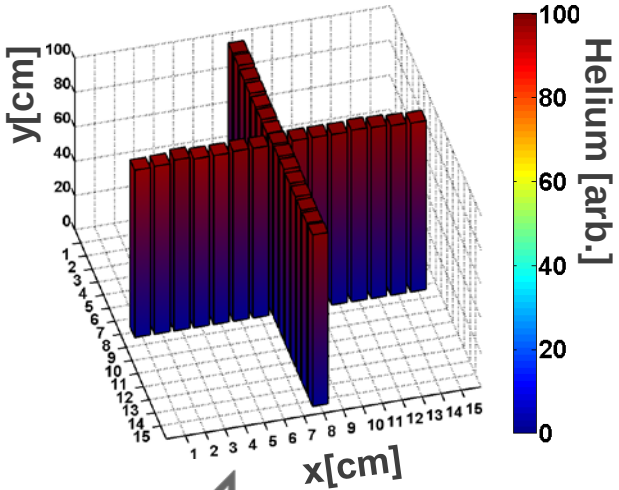


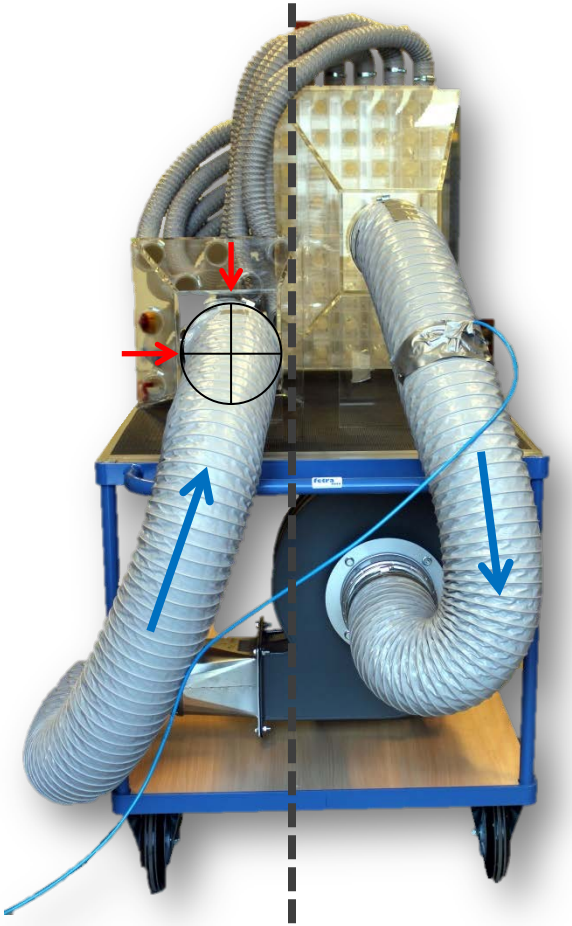
Dynamic measurement

Method of measurement – static measurement

Initial point of measurement



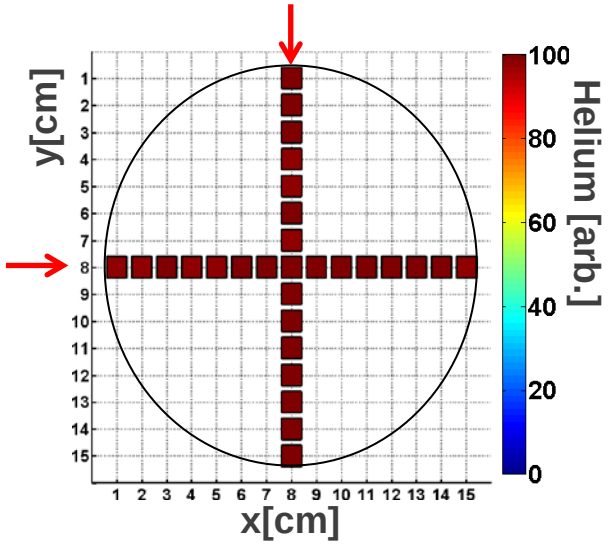


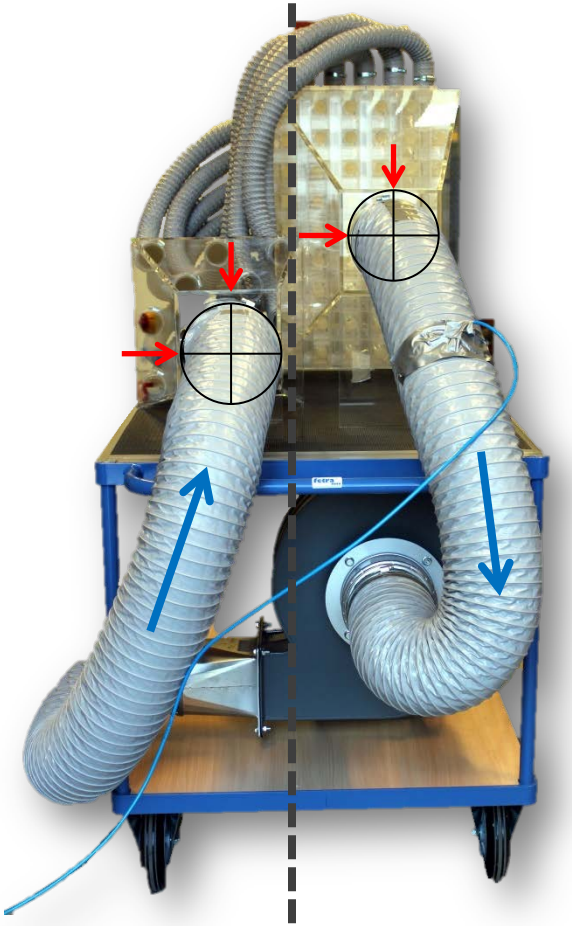


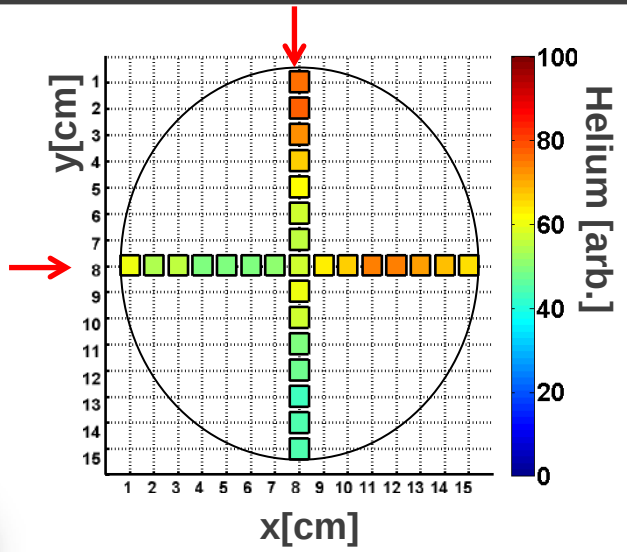
Method of measurement – static measurement

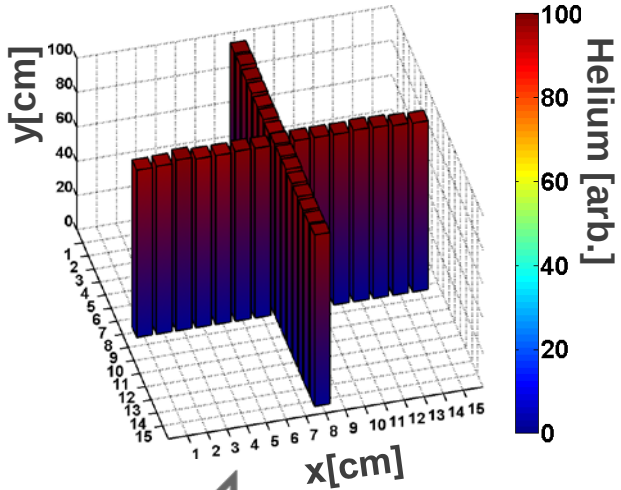
Initial point of measurement

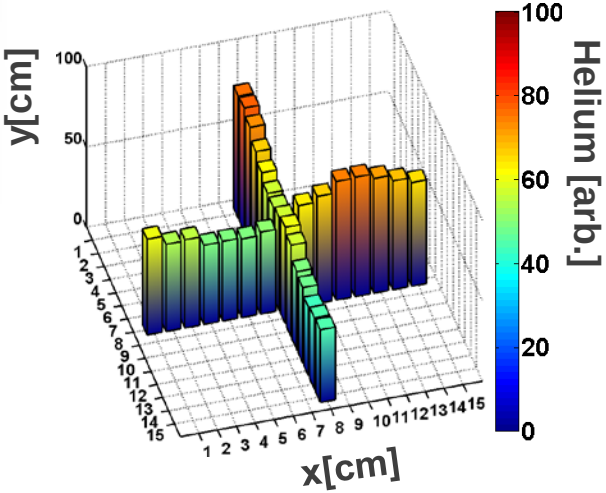
Final point of measurement





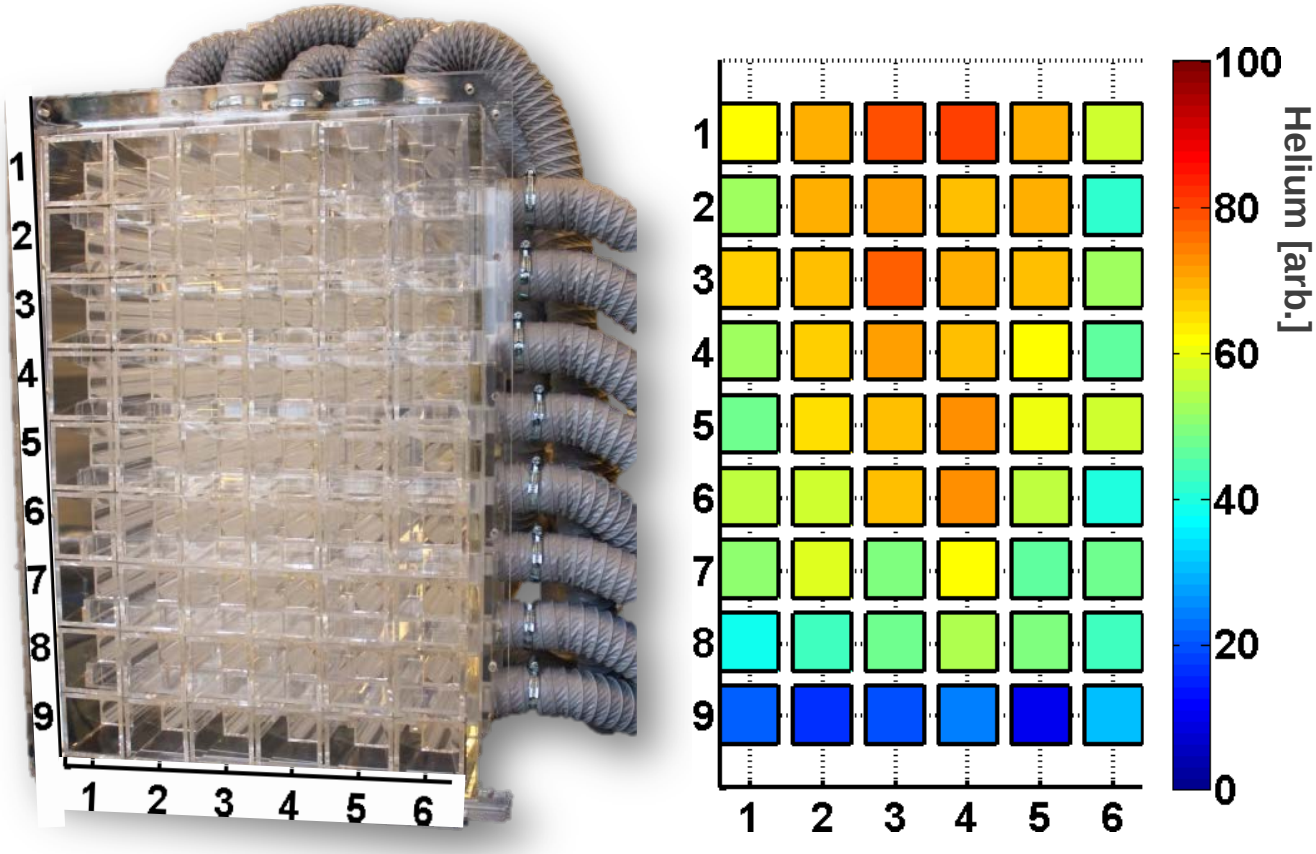






DLR

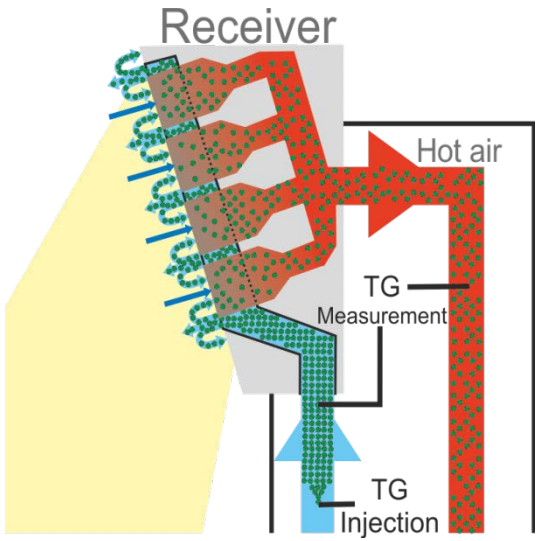
Method of measurement – static measurement



- Only one point of measurement has a homogeneous tracer distribution

→ Static method can only used for validation purposes

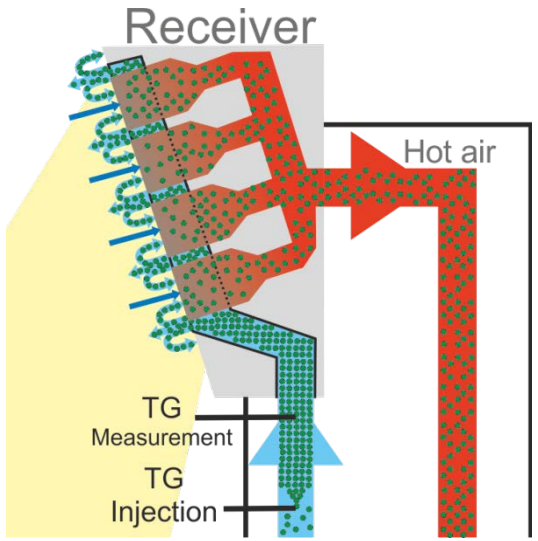
Method of measurement – dynamic measurement



Static measurement

2 points of measurement

$$\mathrm{ARR} = \frac{c_{\mathrm{after}}}{c_{\mathrm{before}}}$$

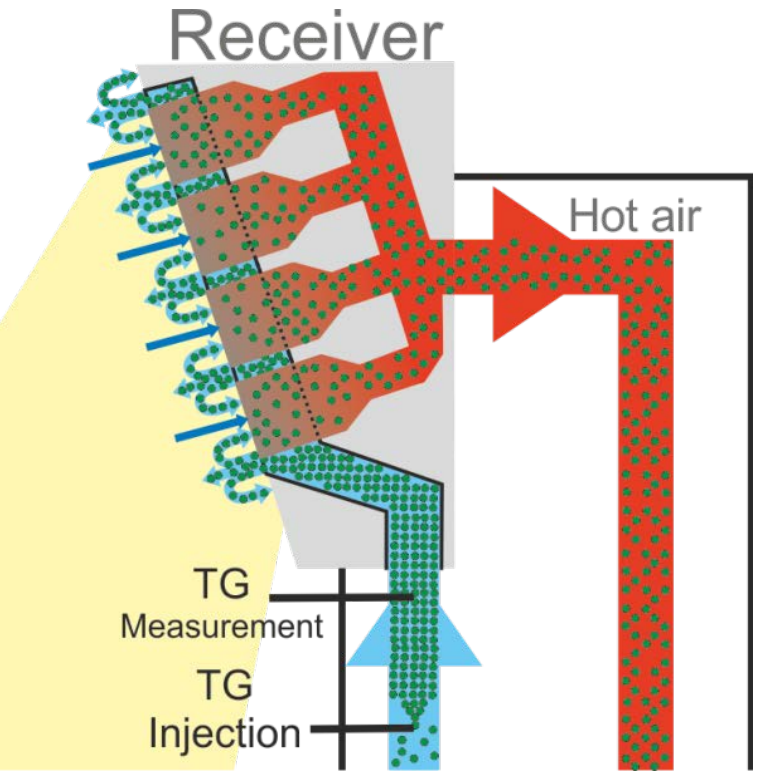


Dynamic measurement

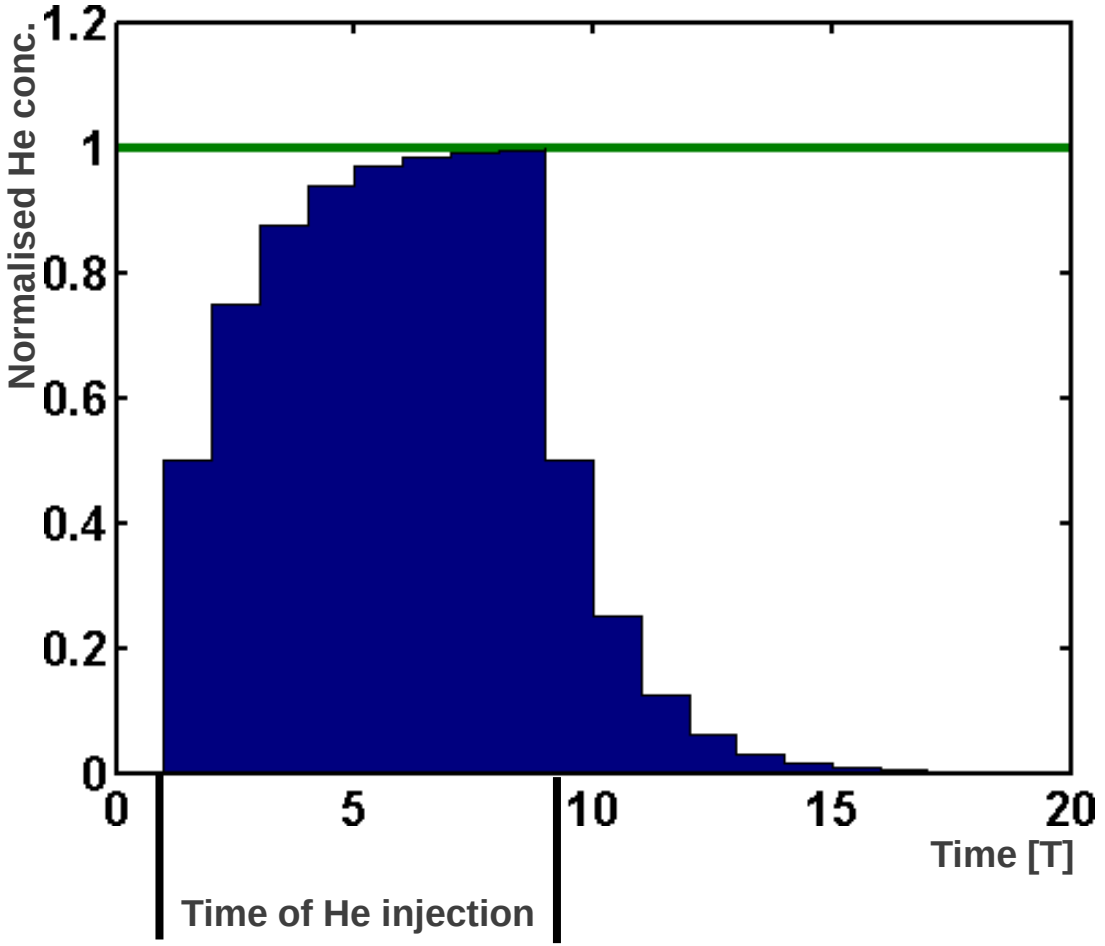
1 point of measurement

ARR from dynamic response

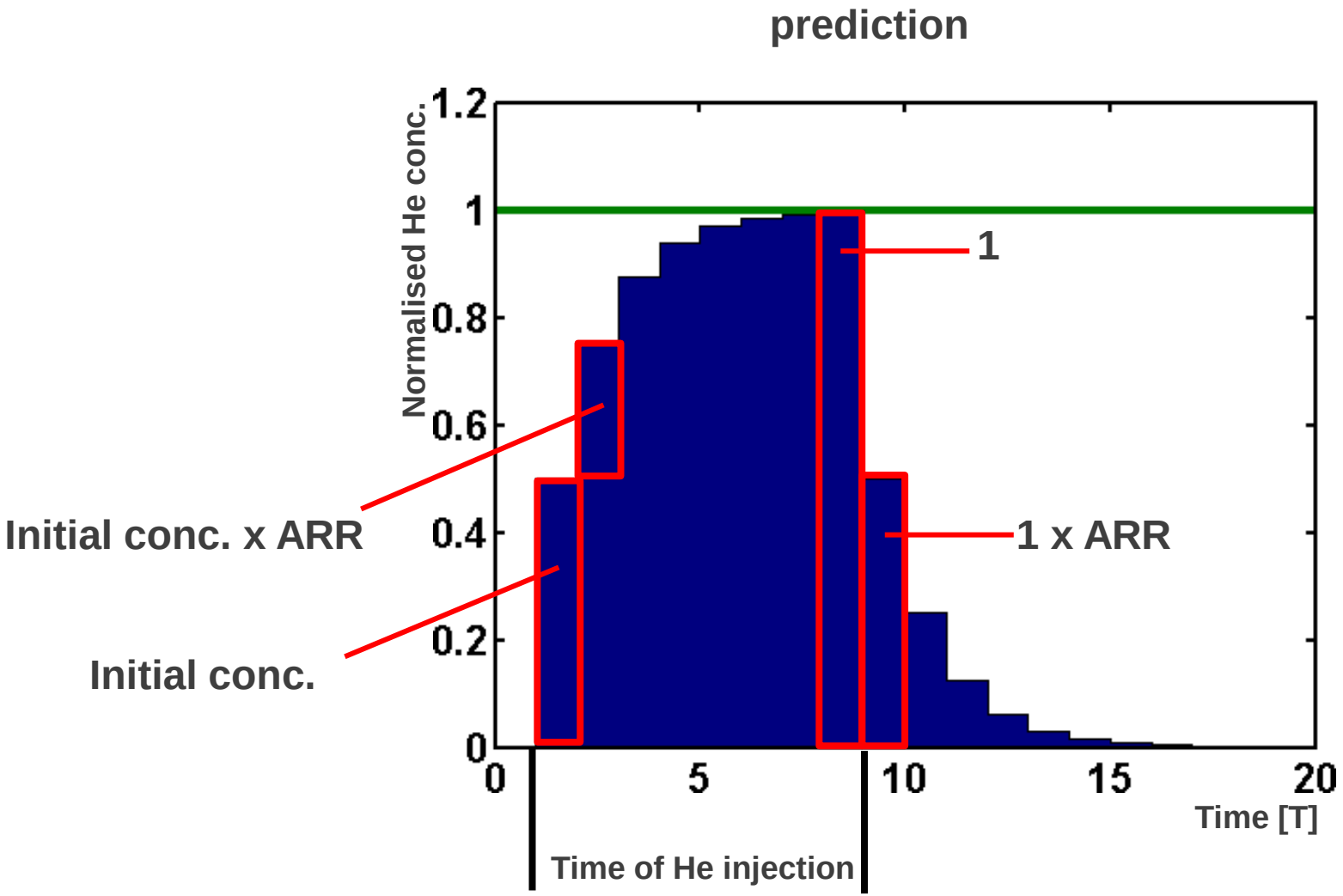
Method of measurement – dynamic measurement



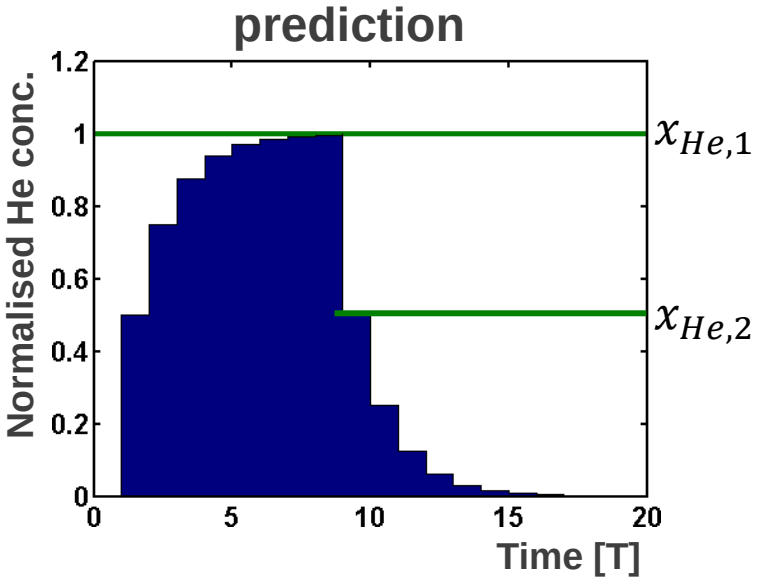
prediction

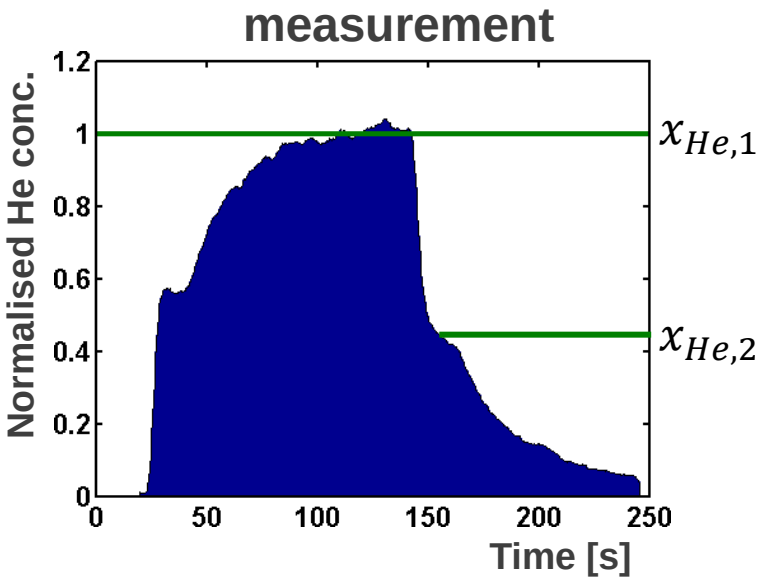


Method of measurement – dynamic measurement



Method of measurement – dynamic measurement





Exemplary determination of the air return ratio:

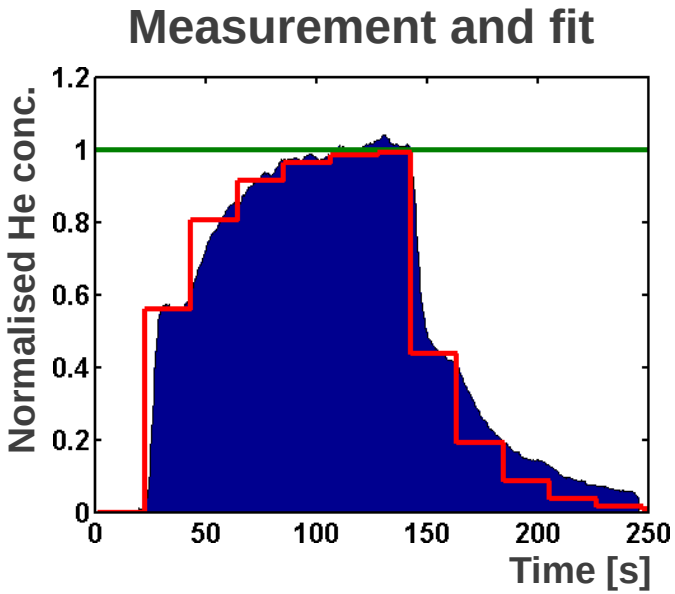
$$ARR = \frac{x_{He,2}}{x_{He,1}} = \frac{0.5}{1} = 50\ \%$$

$$ARR = \frac{x_{He,2}}{x_{He,1}} \approx \frac{0.44}{1} = 44\ \%$$

Prediction has to be fitted in:

- Time
- ARR

Method of measurement – dynamic measurement



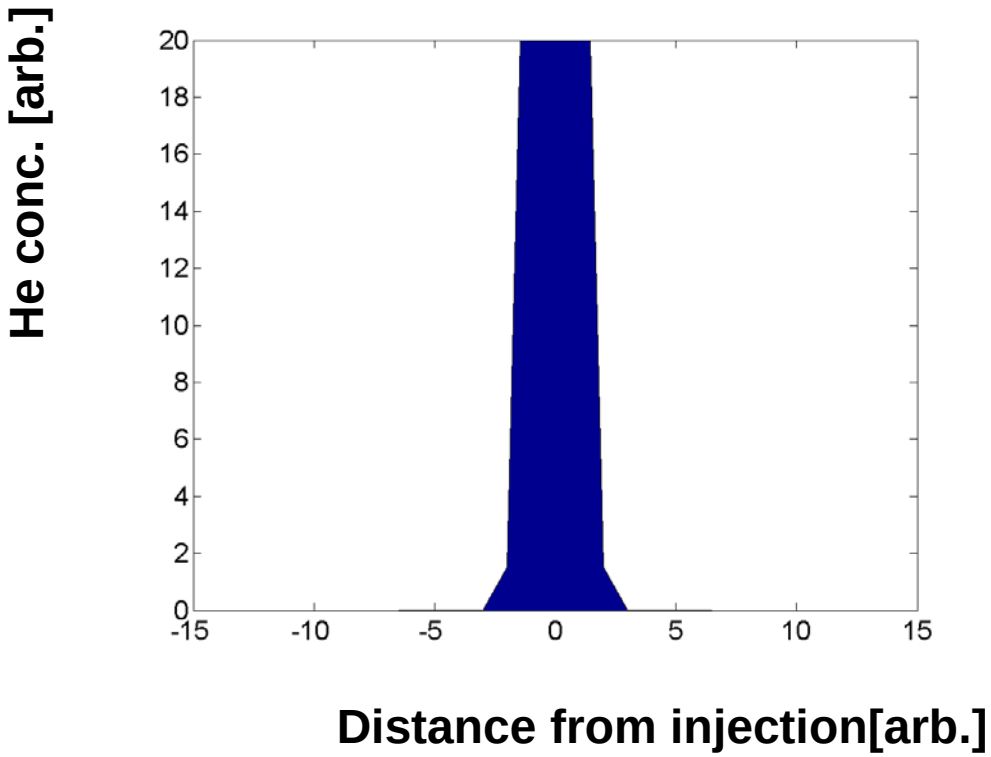
- Time fit creates unnecessary uncertainty
  - Circulation period from measurement
- Tracer dispersion not taken into account
  - Measurements for signal comprehension

Goal: Perfect fit with ARR as only free parameter

- Reducing injection time→0 leads to δ - function
  - Easy determination of circulation period – peak to peak
  - Analytical signal description possible

Method of measurement – dynamic measurement

$$c(x,t) = \frac{N_0}{2A\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$$



Method of measurement – dynamic measurement

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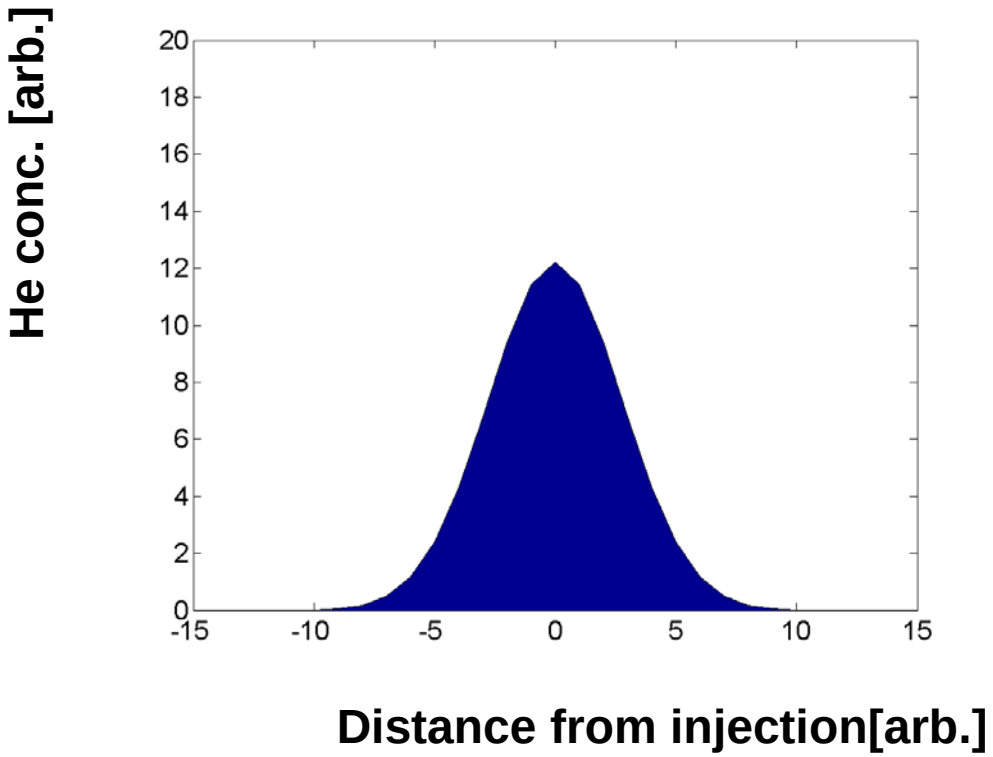

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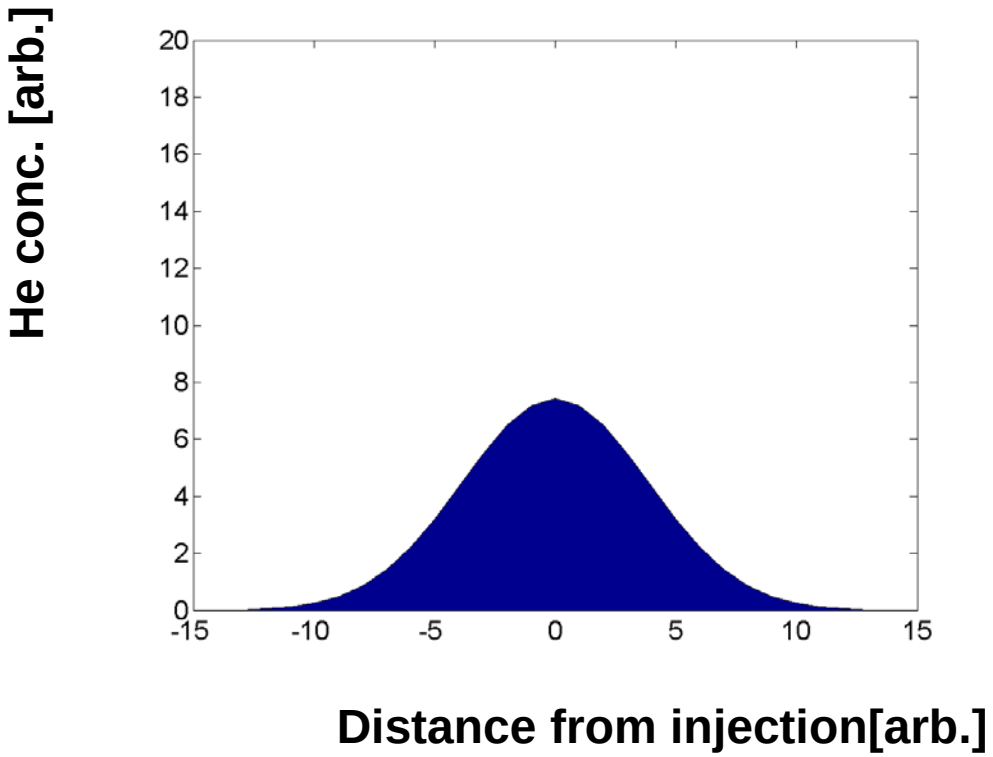

Method of measurement – dynamic measurement

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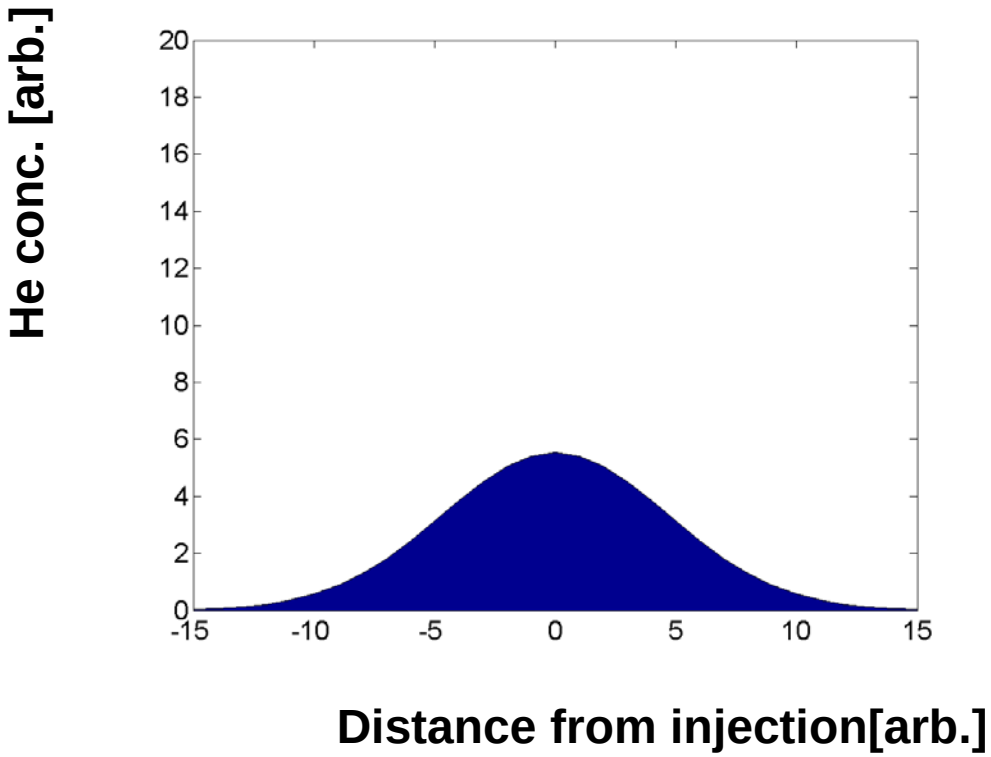
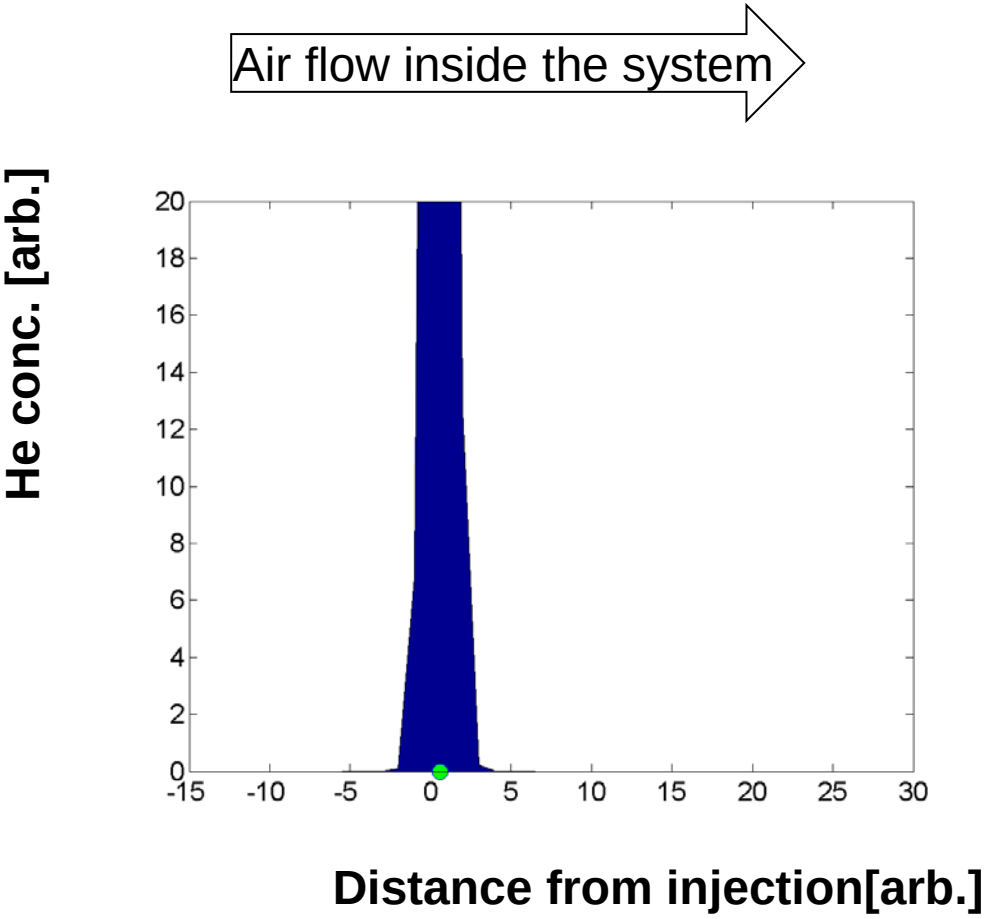
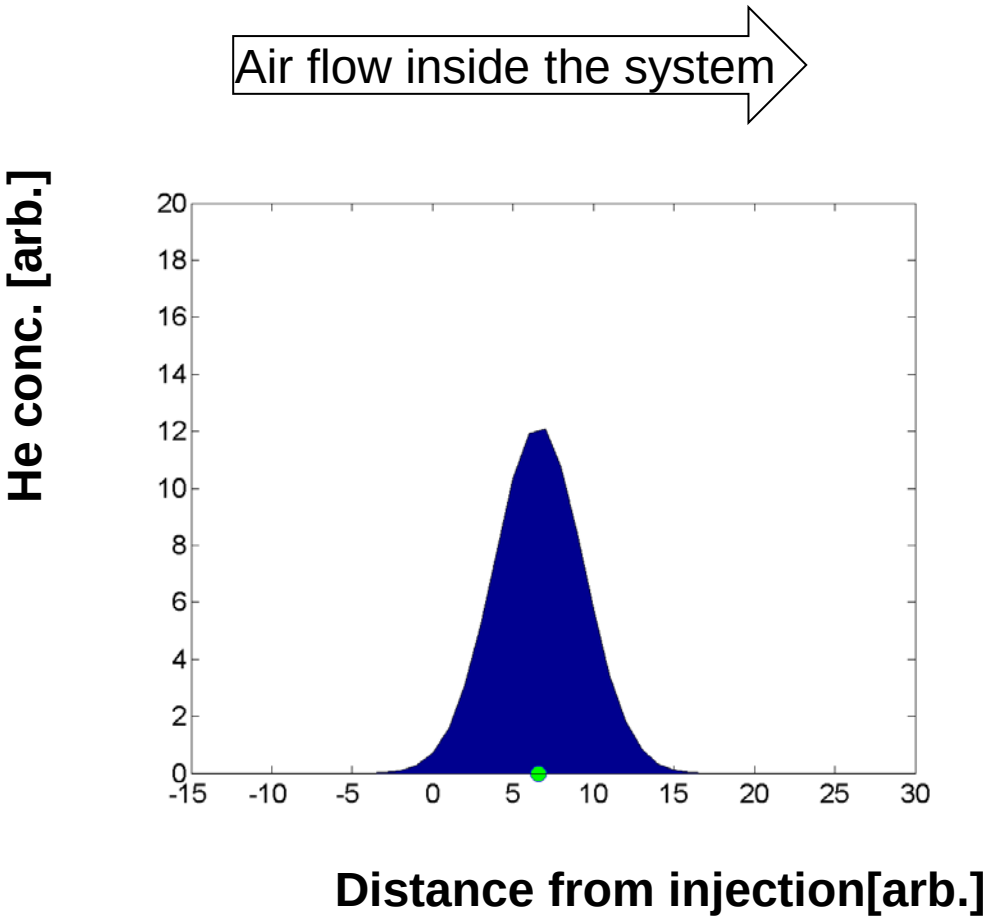


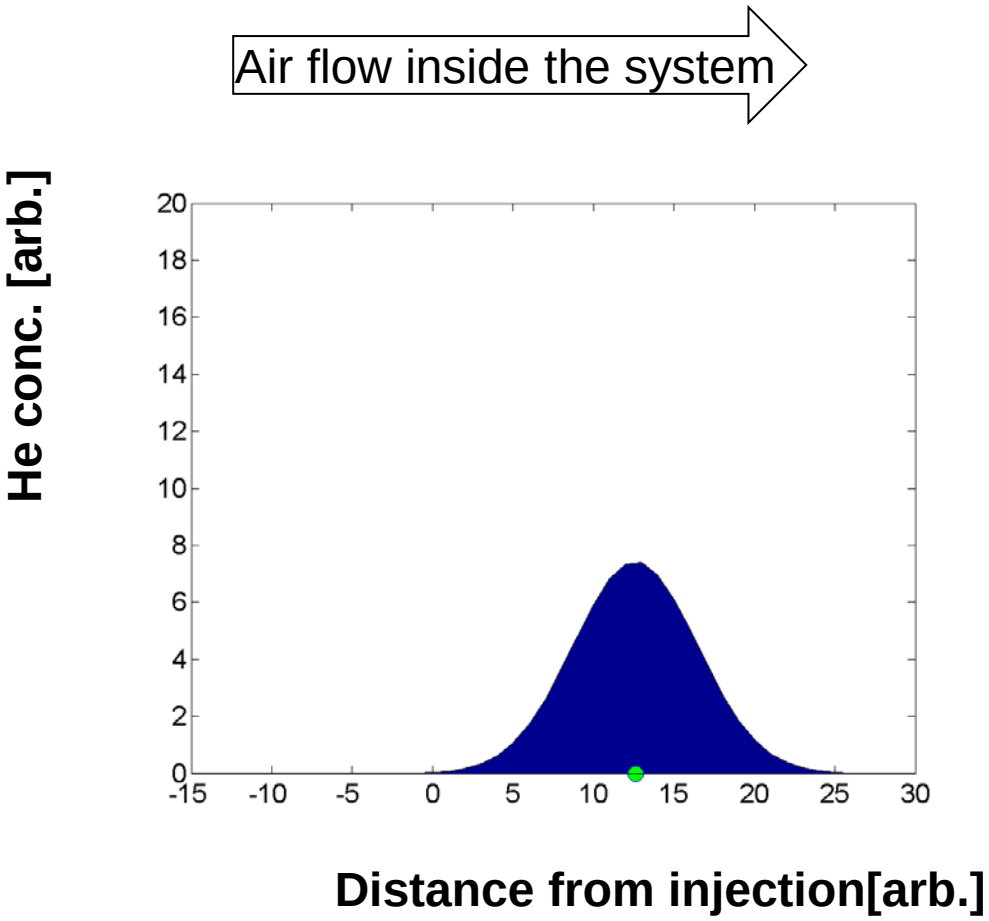
Method of measurement – dynamic measurement



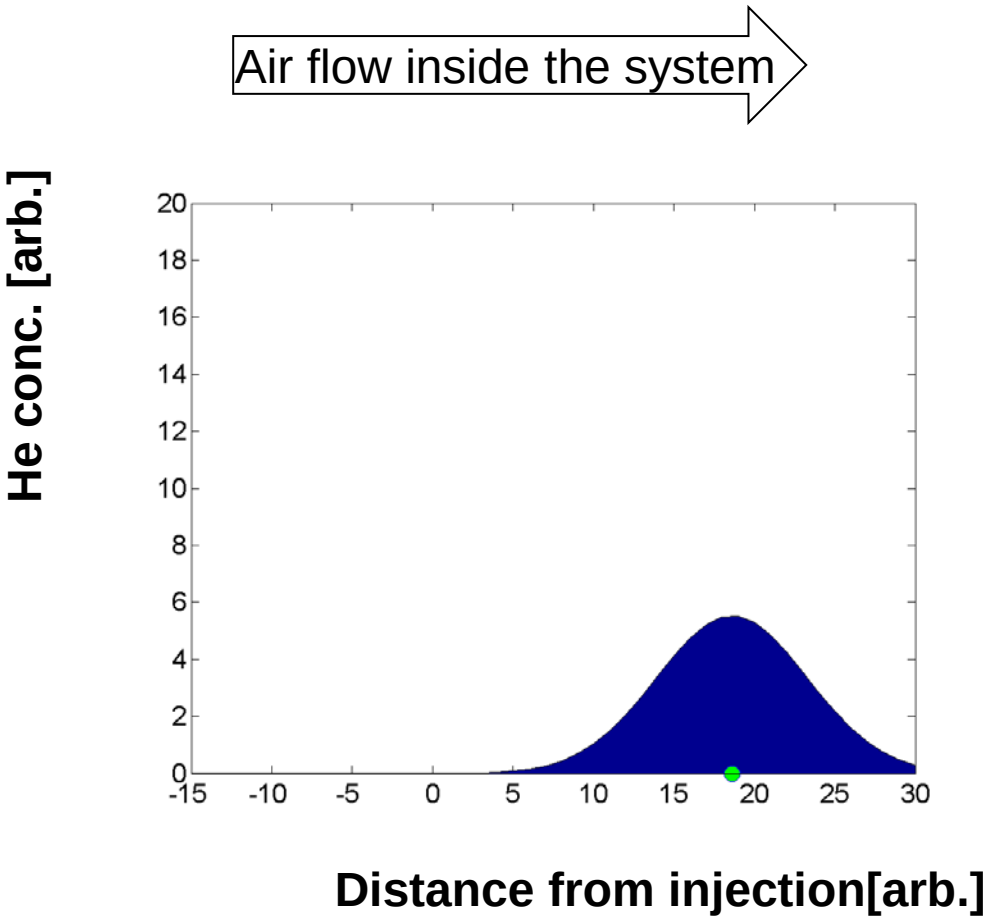
Method of measurement – dynamic measurement



Method of measurement – dynamic measurement

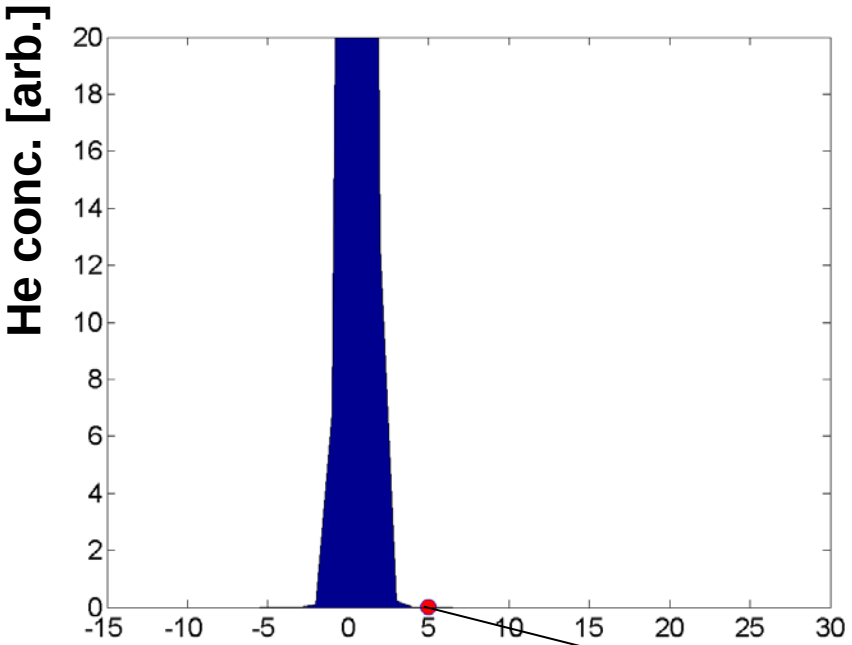


Method of measurement – dynamic measurement



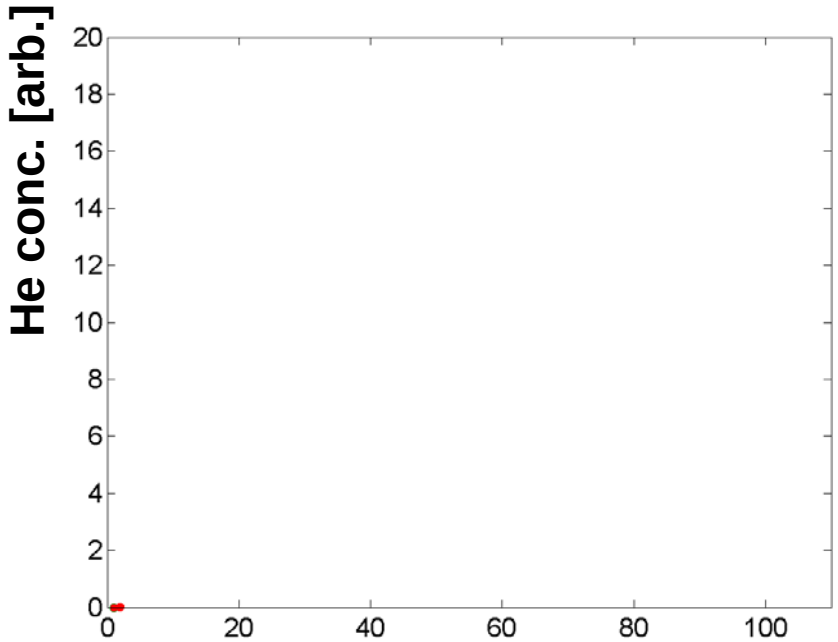
Method of measurement – dynamic measurement

Air flow inside the system



Distance from injection[arb.]

Predicted measurement

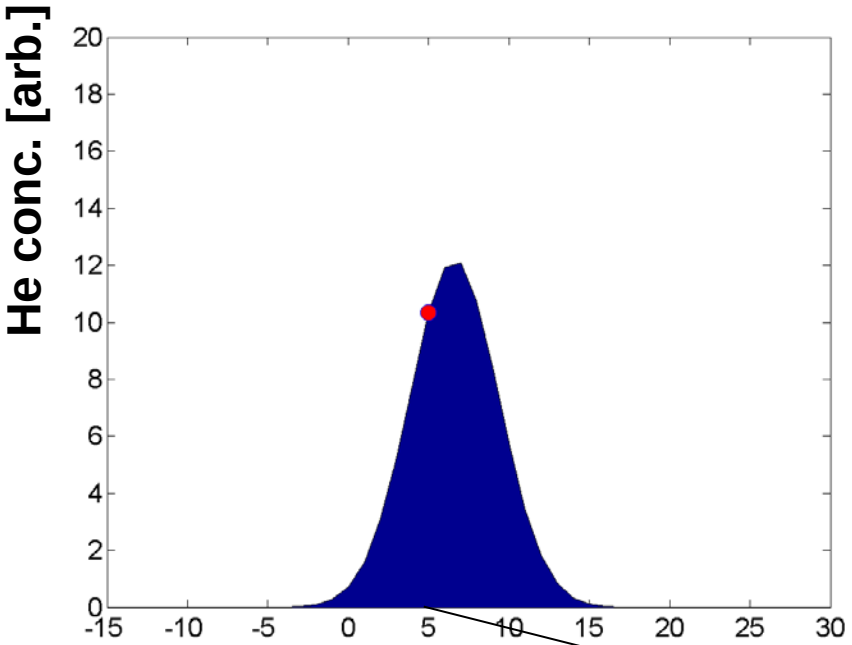


Time [arb.]

Point of measurement

Method of measurement – dynamic measurement

Air flow inside the system



Distance from injection[arb.]

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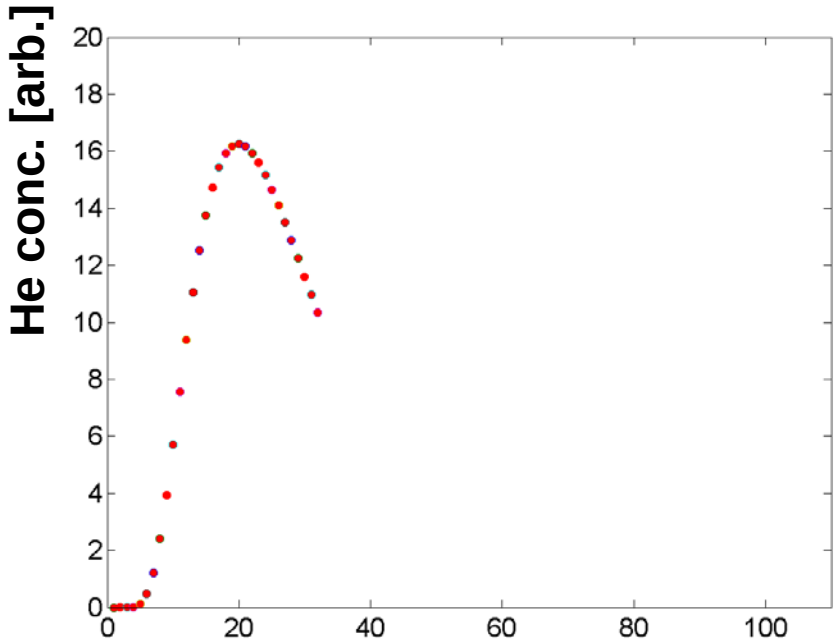
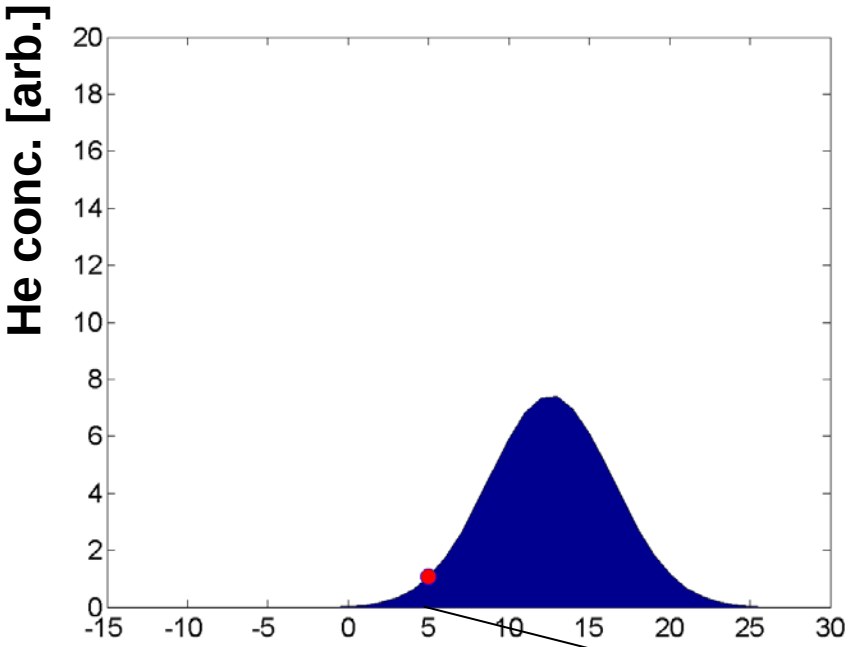


Time [arb.]

Point of measurement

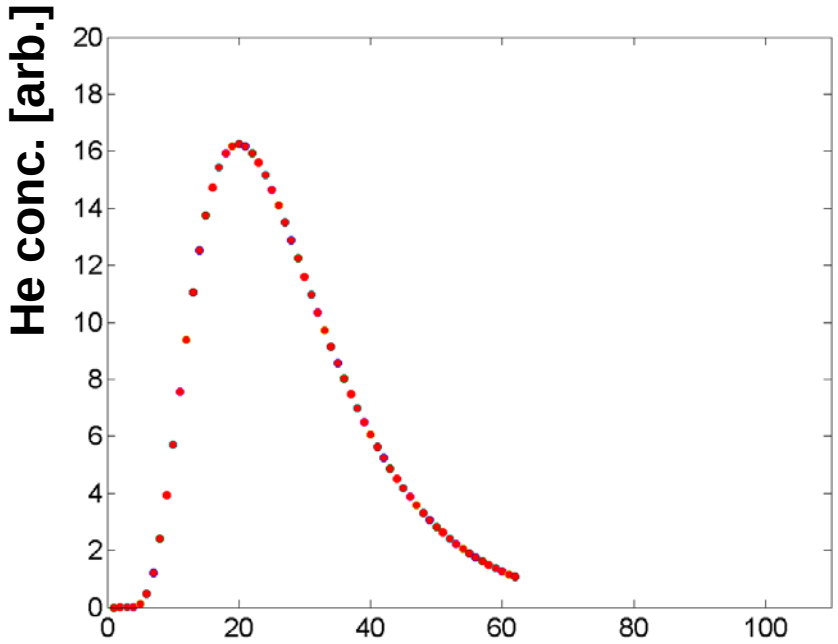
Method of measurement – pulsed measurement

Air flow inside the system



Distance from injection[arb.]

Predicted measurement

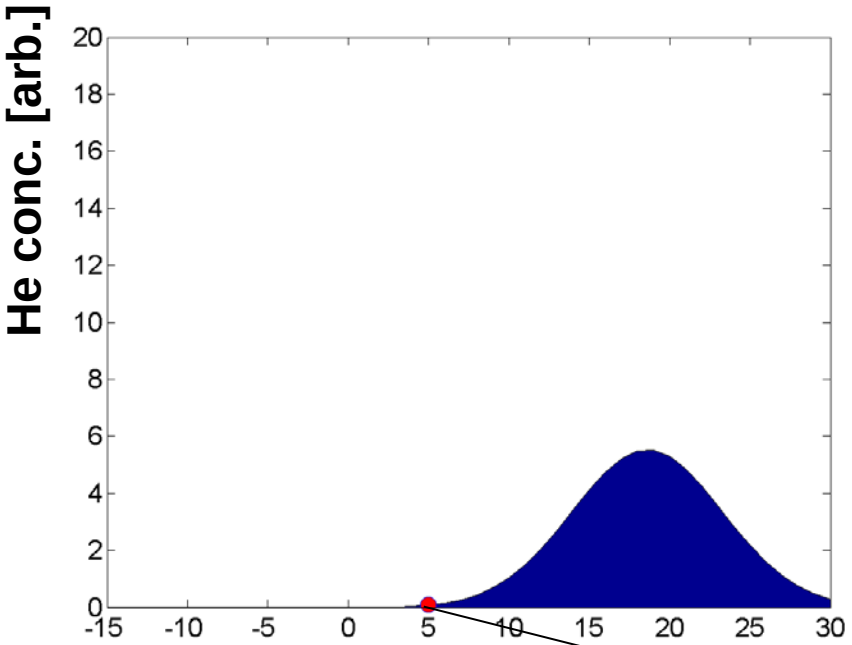


Time [arb.]

Point of measurement

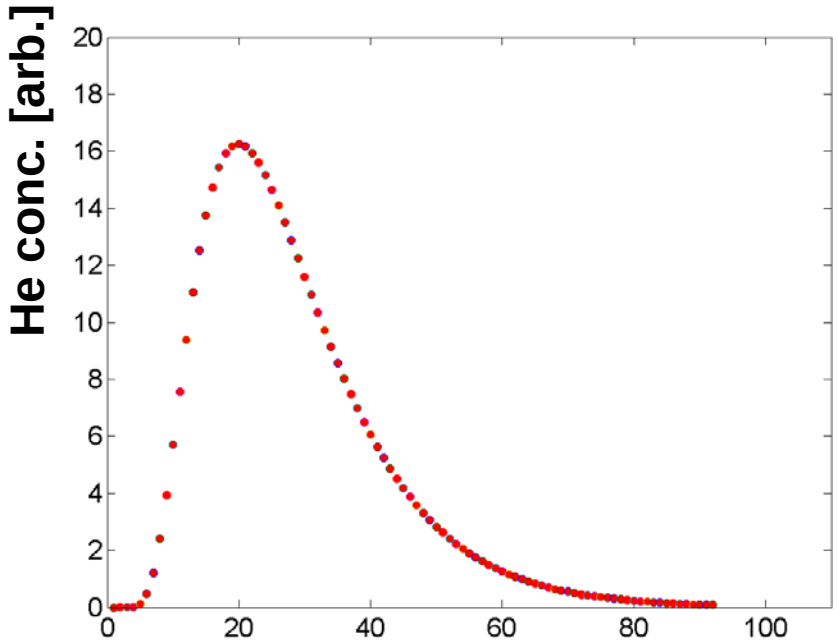
Method of measurement – dynamic measurement

Air flow inside the system



Distance from injection[arb.]

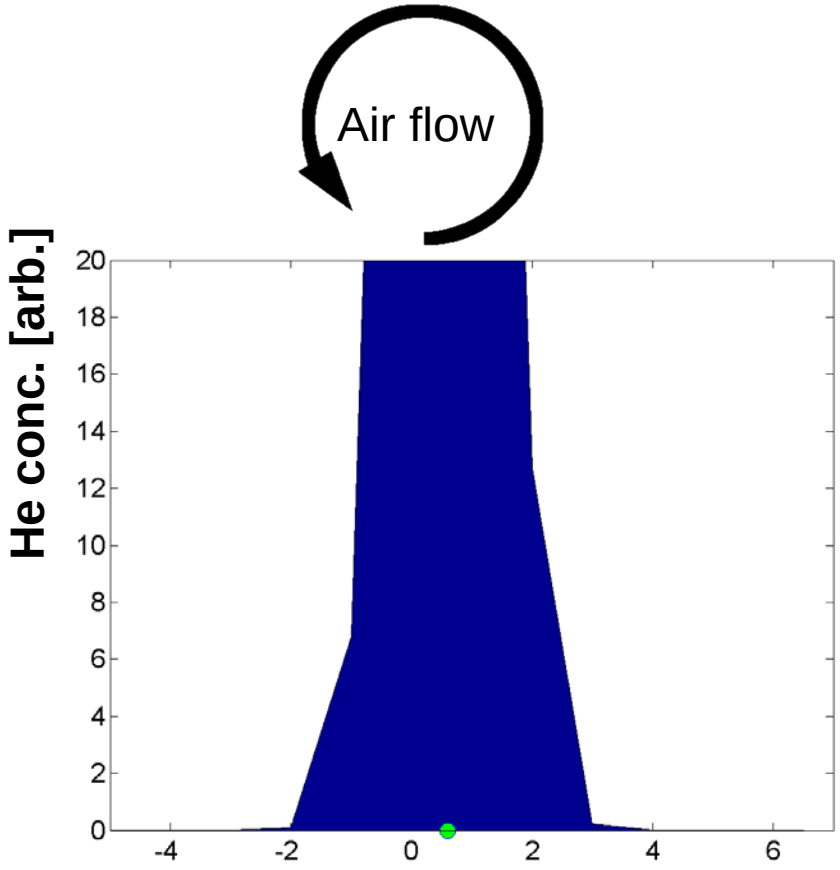
Predicted measurement



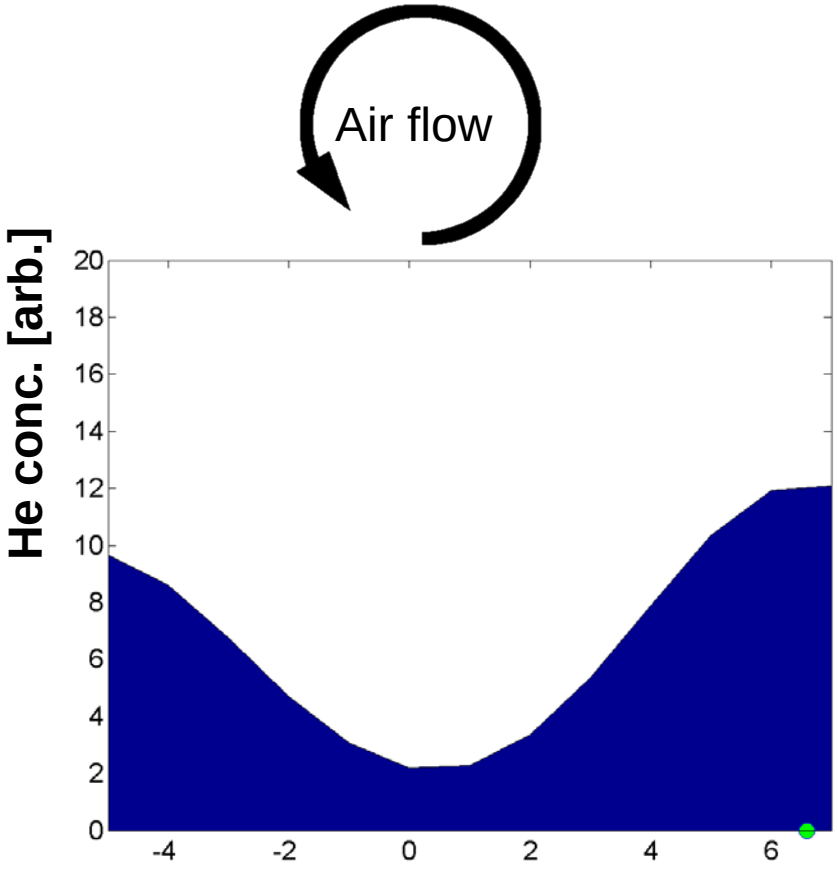
Time [arb.]

Point of measurement

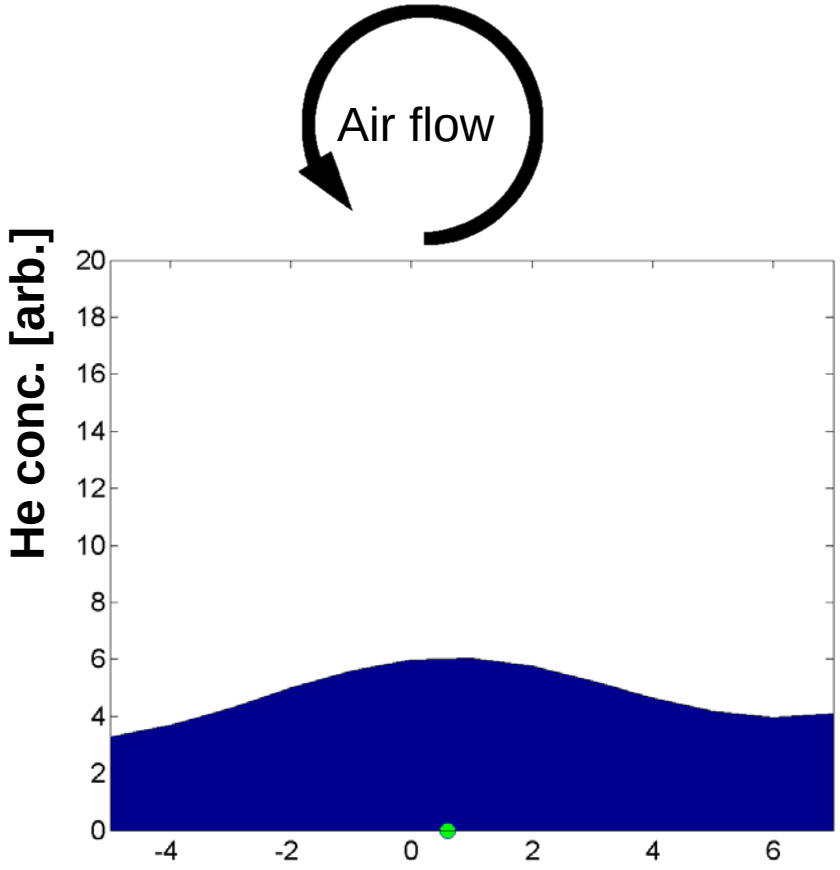
Method of measurement – dynamic measurement



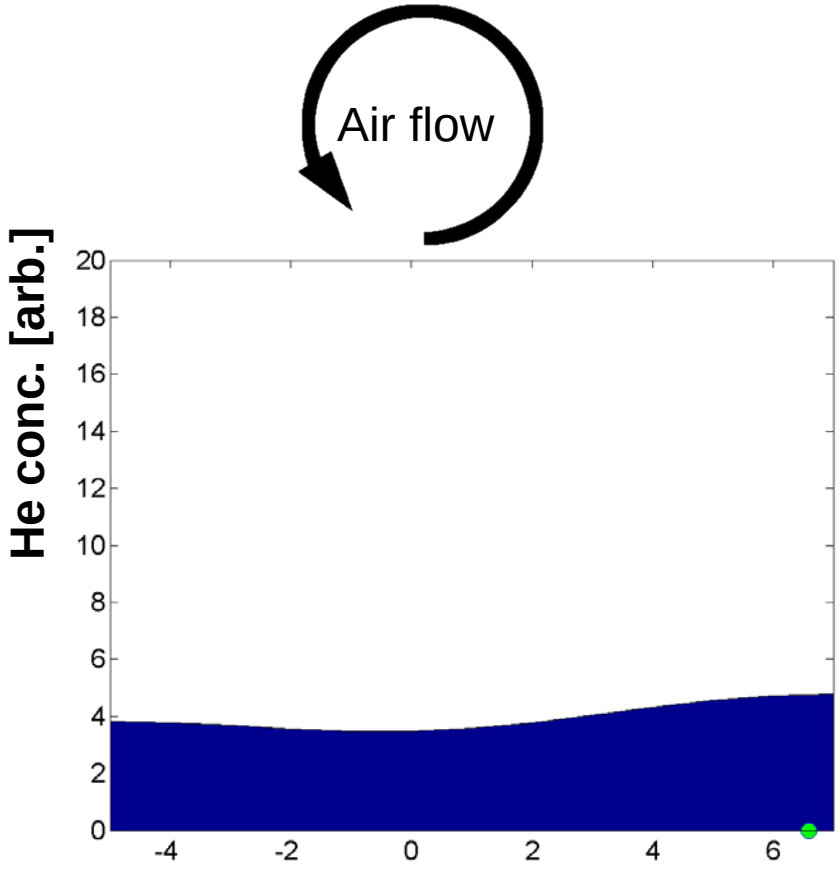
Method of measurement – dynamic measurement



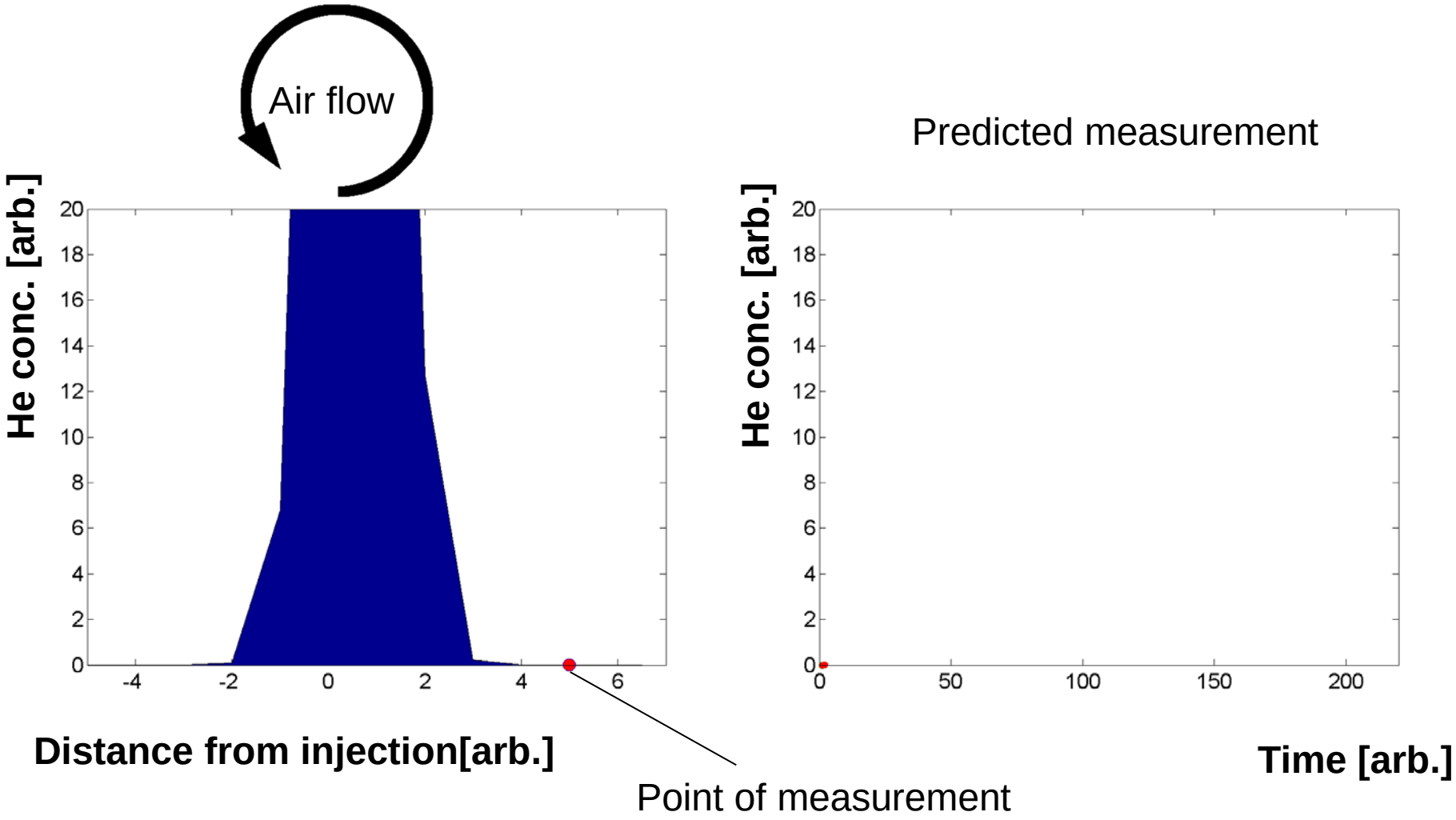
Method of measurement – dynamic measurement



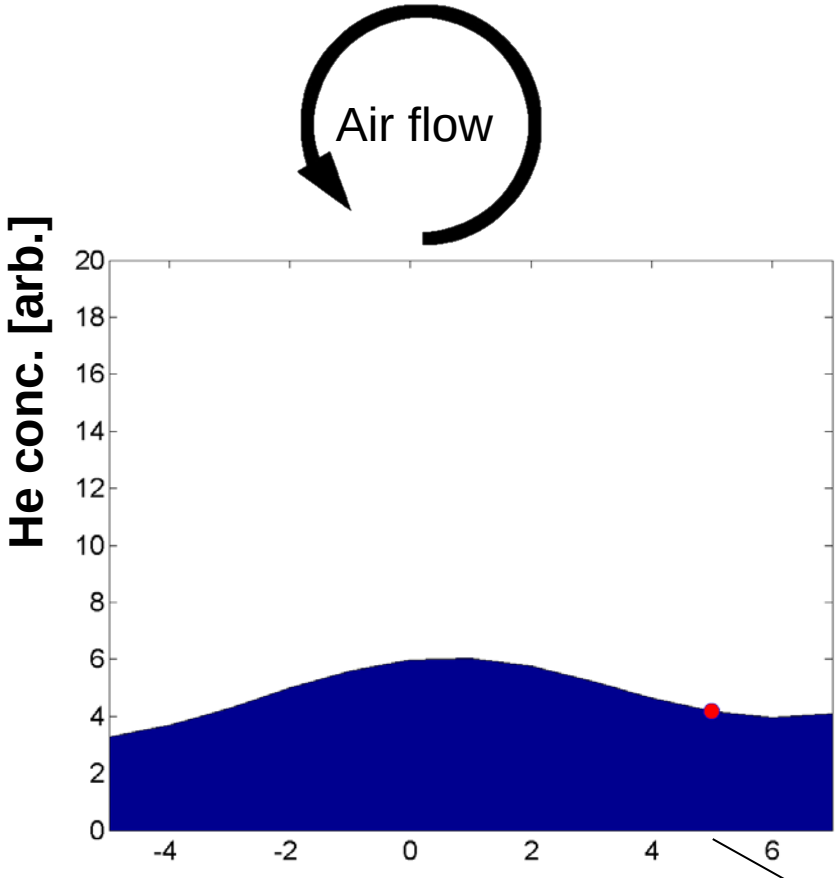
Method of measurement – dynamic measurement



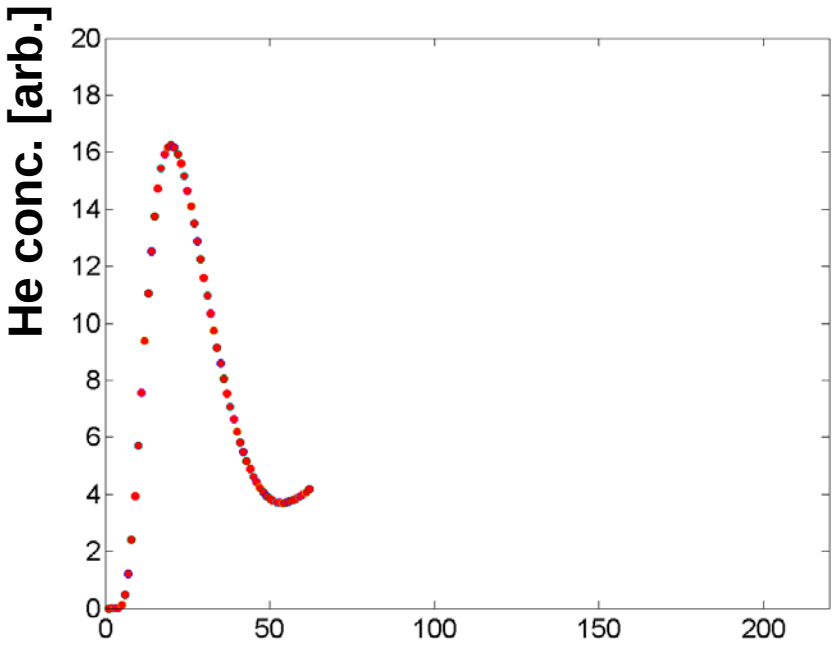
Method of measurement – dynamic measurement



Method of measurement – dynamic measurement

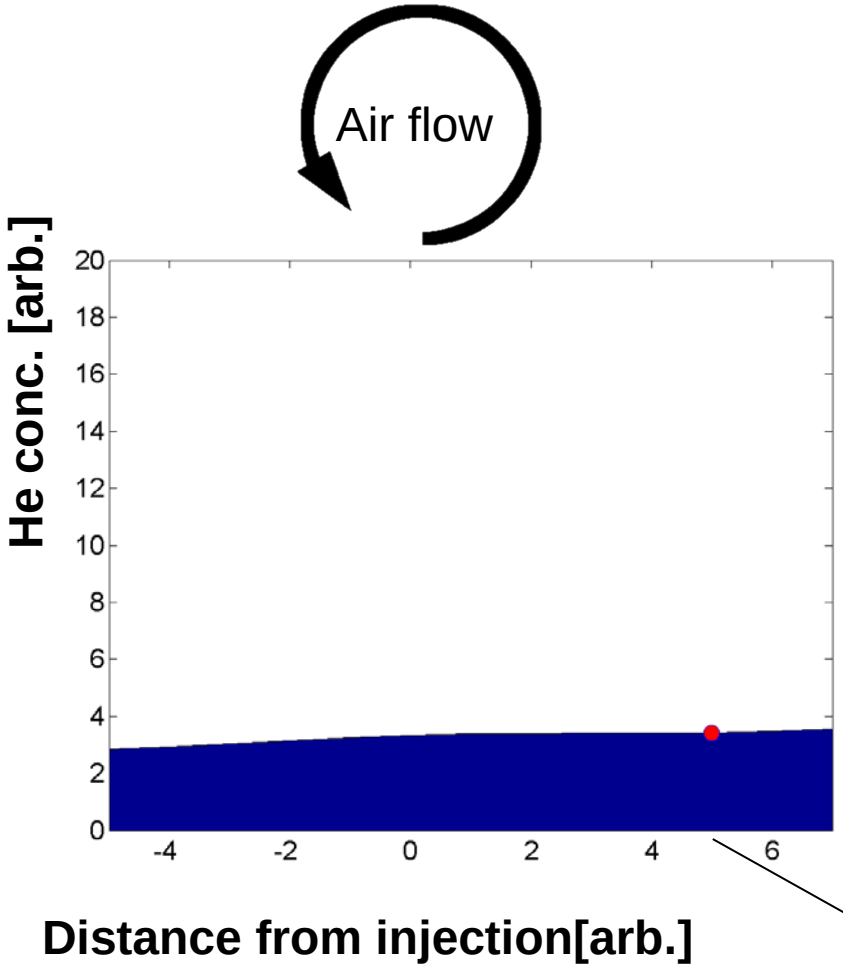


Predicted measurement

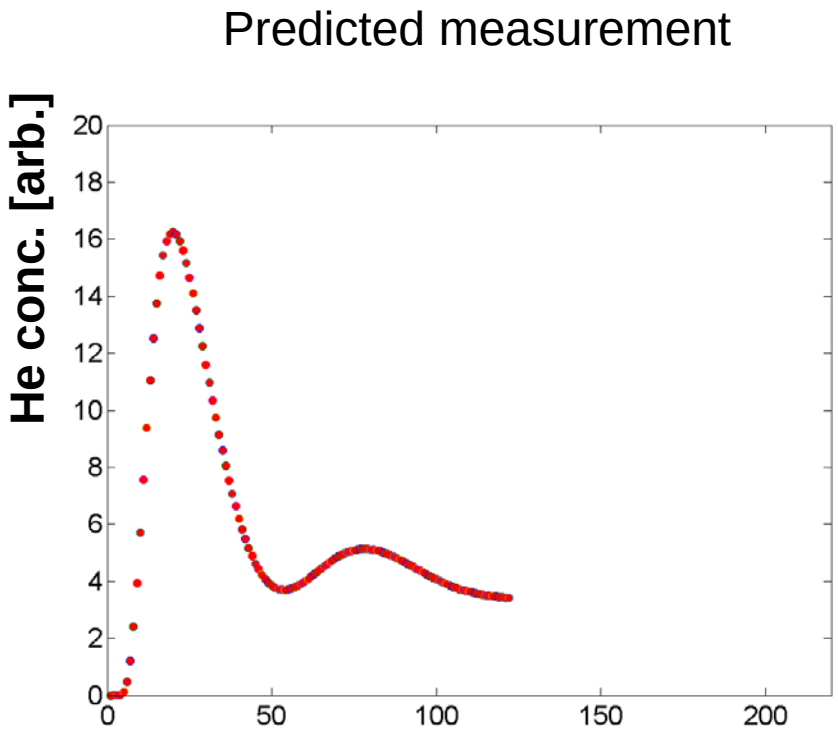


Point of measurement

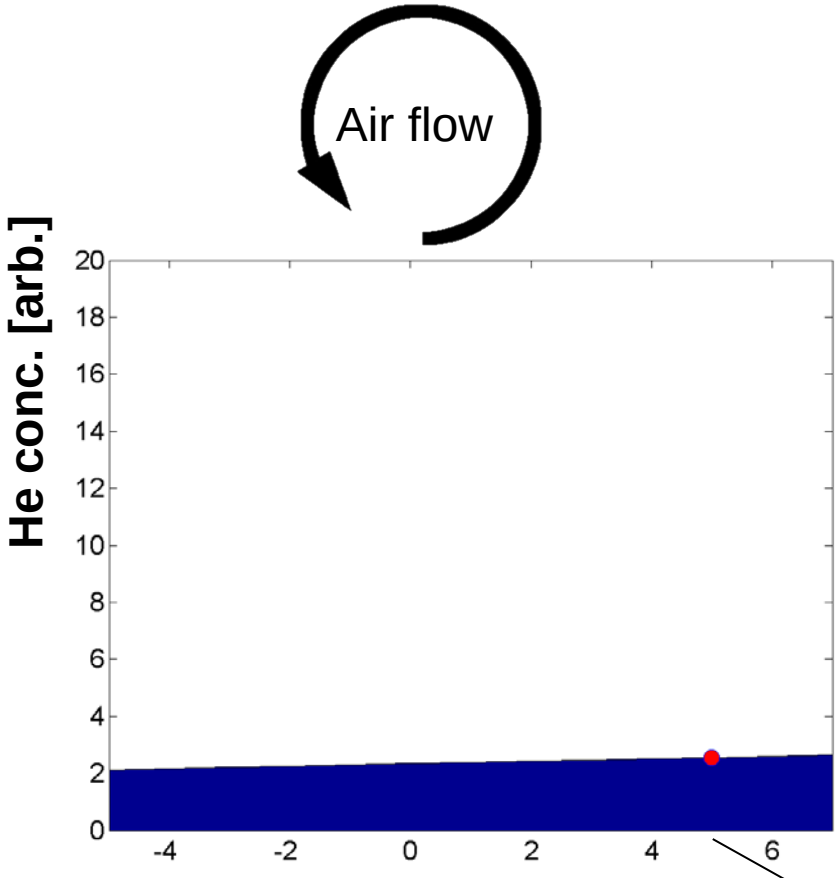
Method of measurement – dynamic measurement



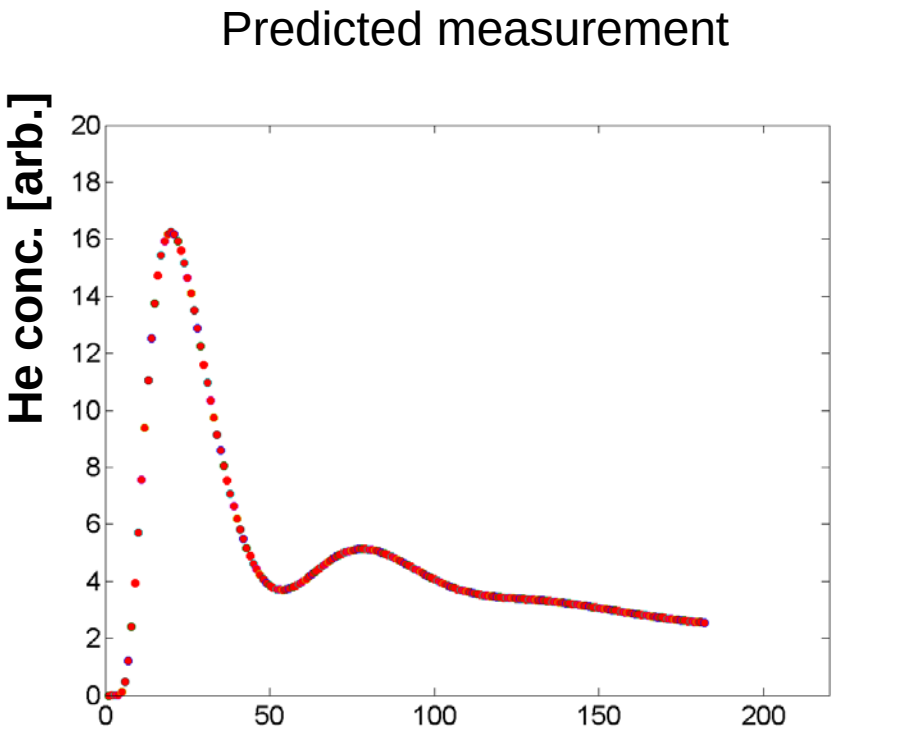
Point of measurement



Method of measurement – dynamic measurement

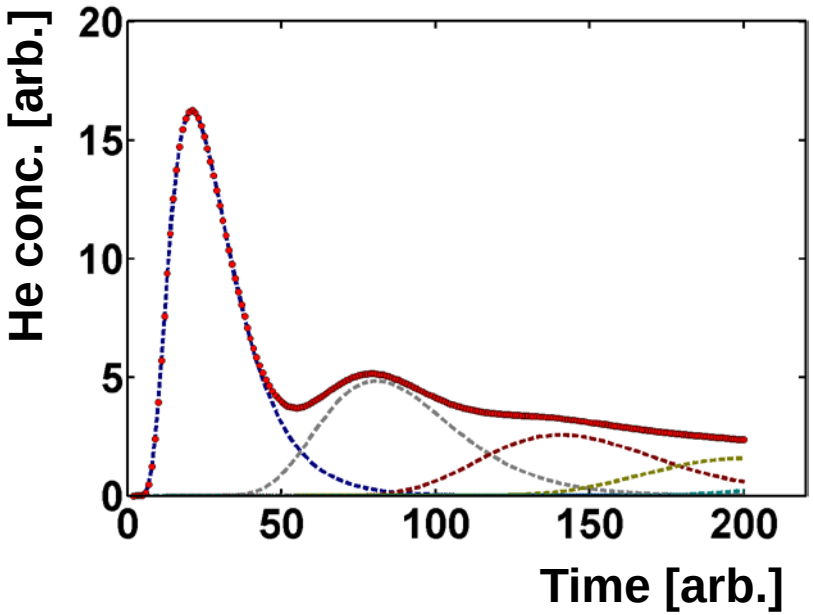


Point of measurement

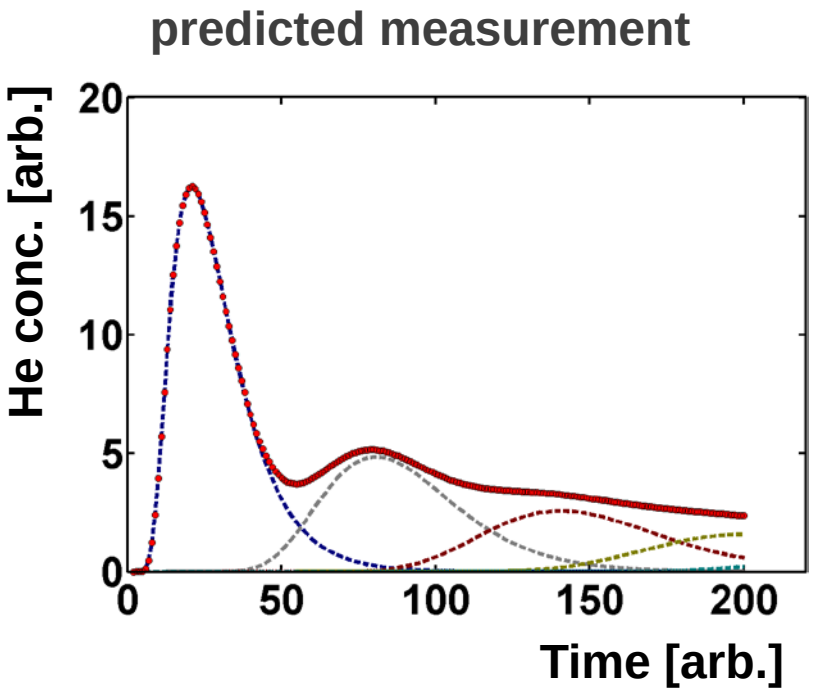


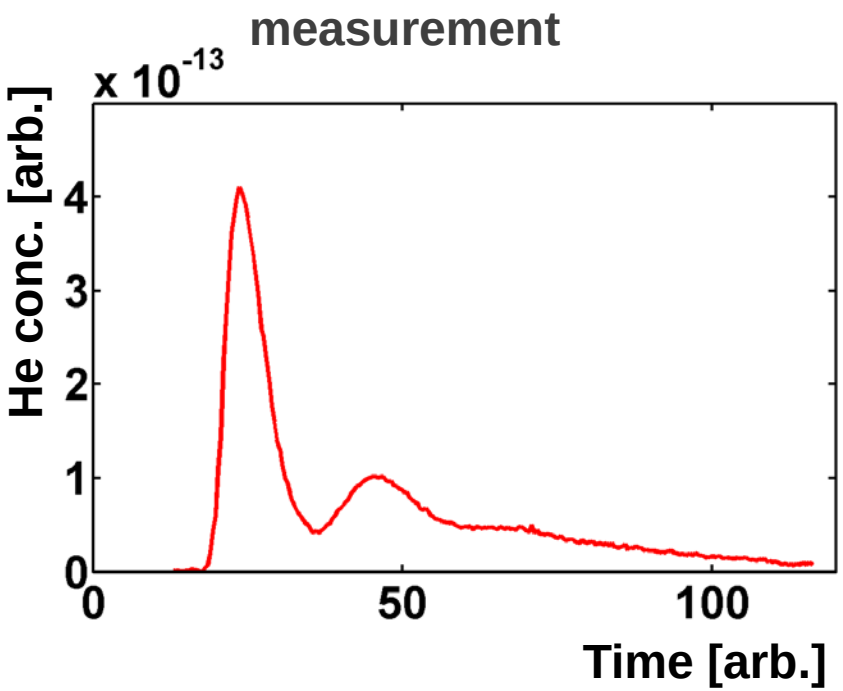
Method of measurement – dynamic measurement

predicted measurement



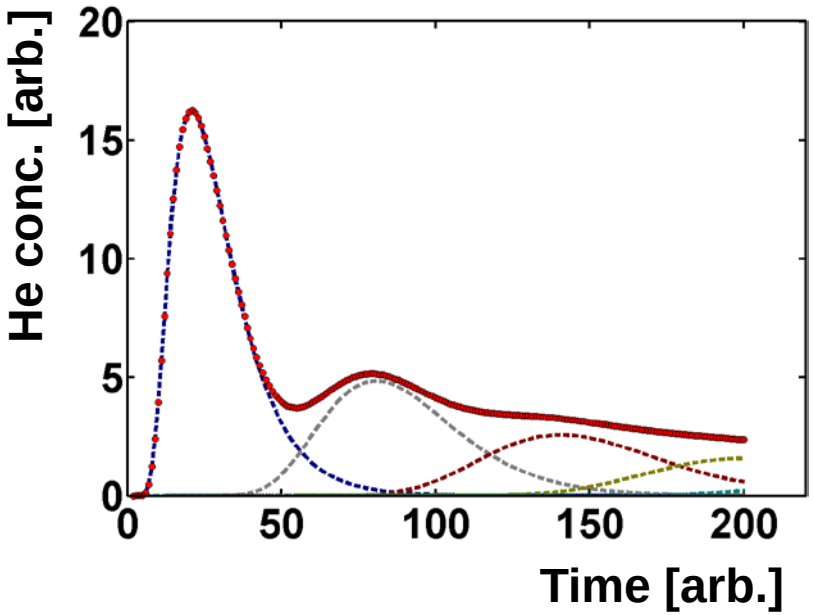
Method of measurement – dynamic measurement



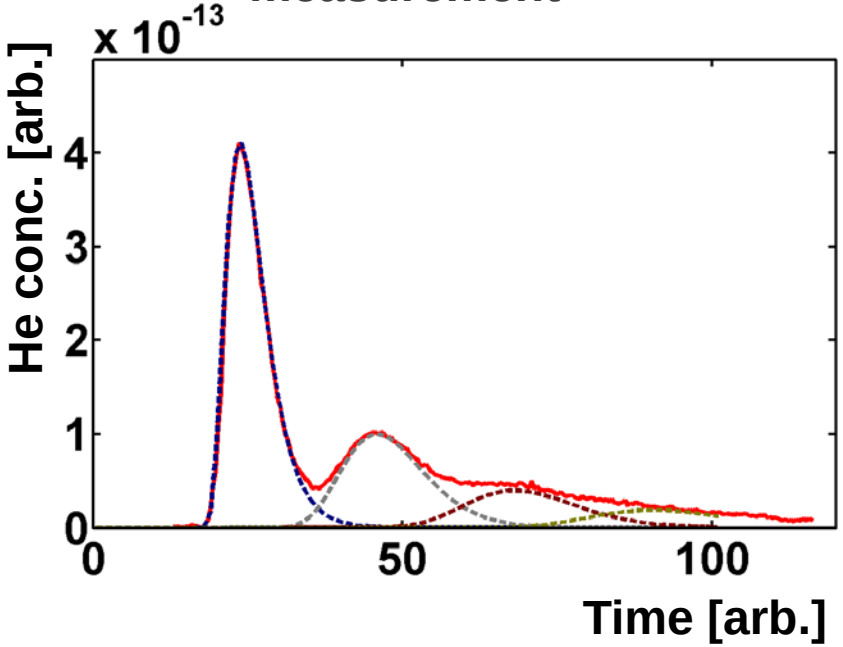


Method of measurement – dynamic measurement

predicted measurement

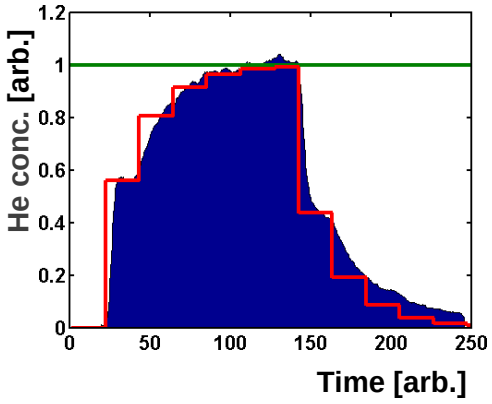


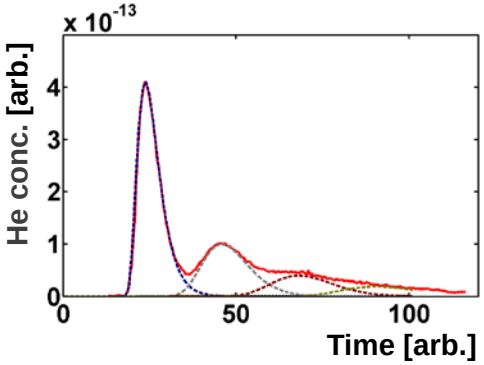
measurement

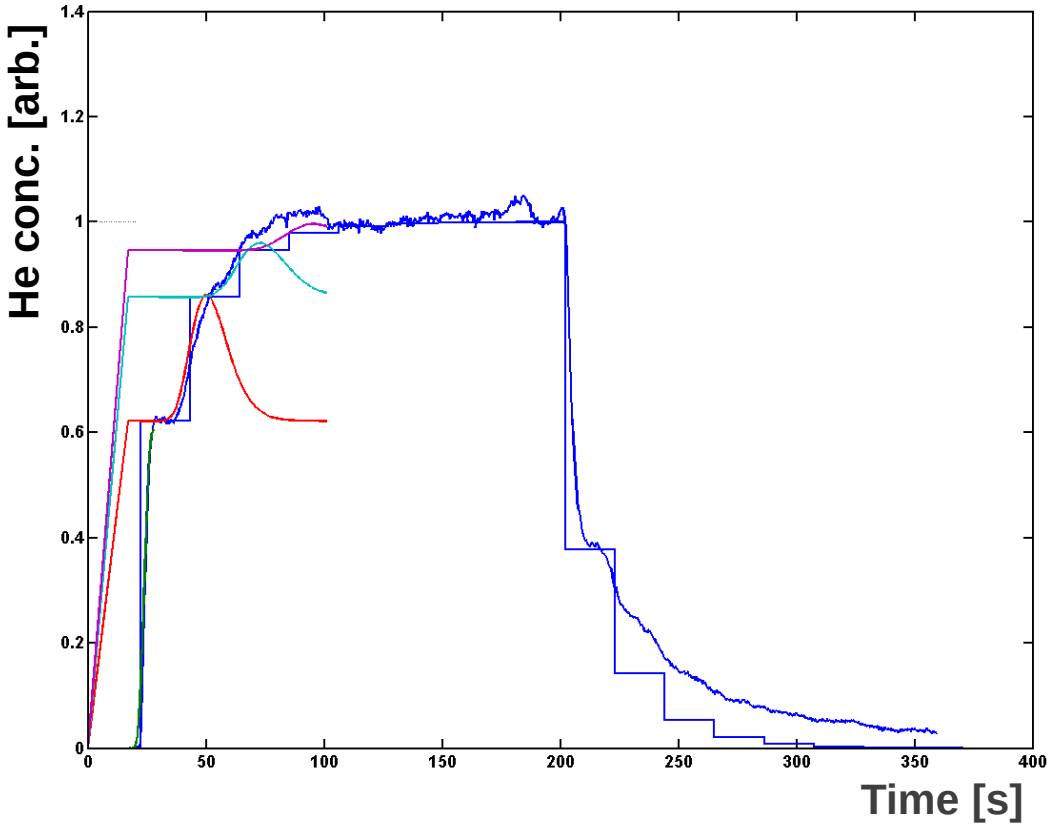


Method of measurement – dynamic measurement

work in progress

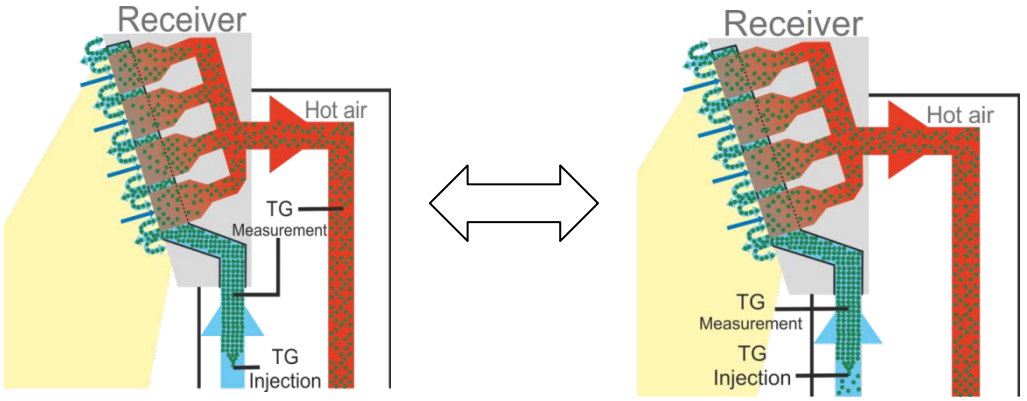






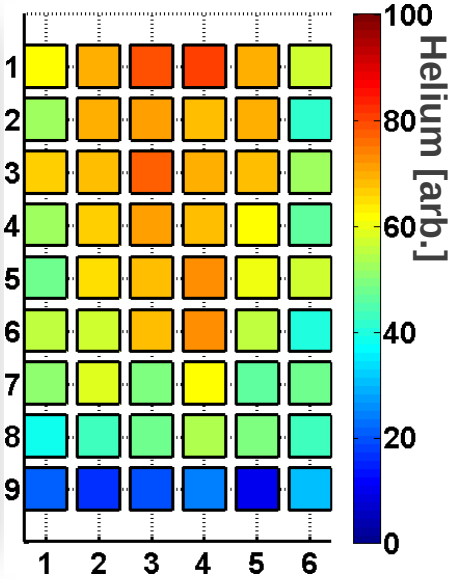
Validation

Internal



Further: 100%ARR rate, He→CO_2

External

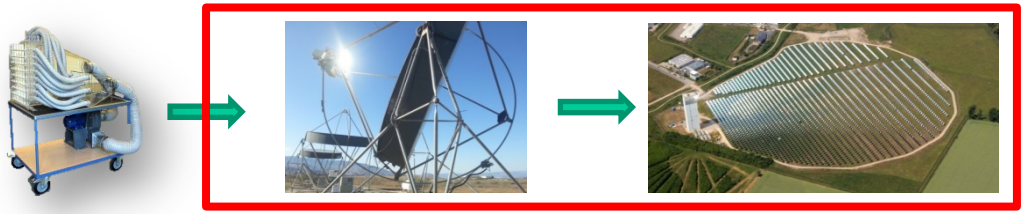


Further: CFD

Summary & Outlook

- A measurement technique for the ARR has been developed
- First experimental results match the predictions

- Full signal description has to be developed
- Extensive validation of the measurement technique
- Application of the tracer gas technique at Dish & Solar Tower Jülich



Ministerium für Innovation,
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Summary & Outlook

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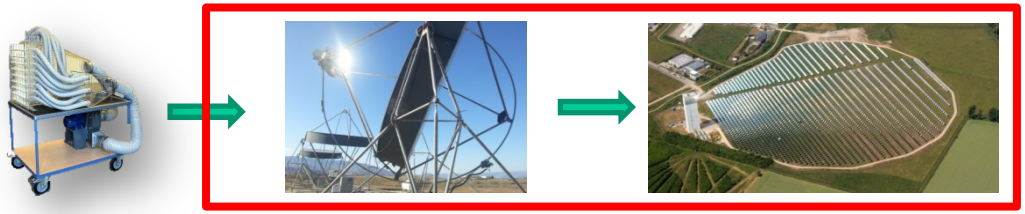

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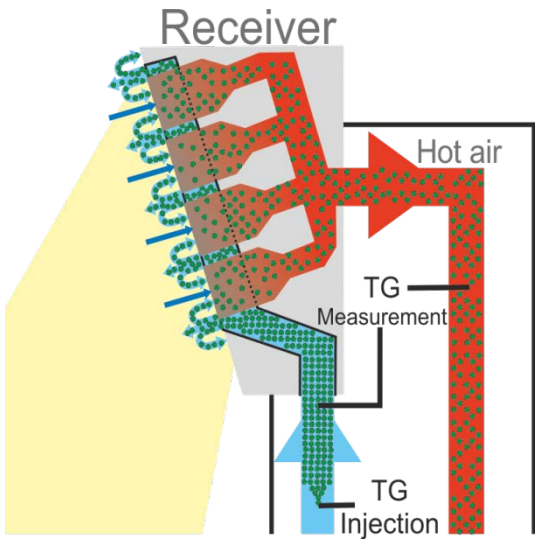
des Landes Nordrhein-Westfalen

Thank you !

DLR

Backup Slides

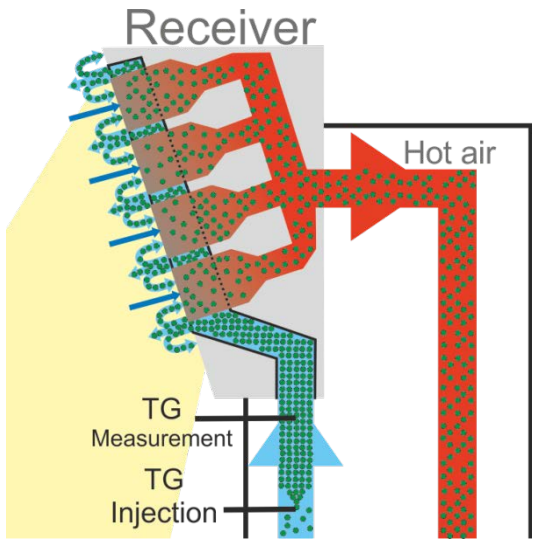
Method of measurement –



Static measurement

2 points of measurement

$$\mathrm{ARR} = \frac{c_{\mathrm{after}}}{c_{\mathrm{before}}}$$

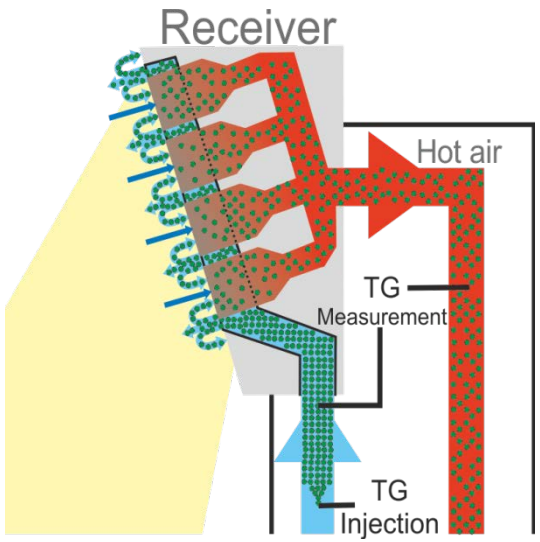


Dynamic measurement

1 point of measurement

ARR from dynamic response

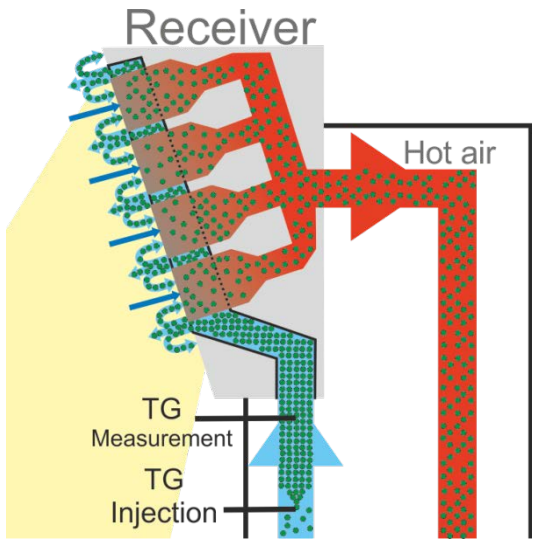
Method of measurement –



Static measurement

2 points of measurement

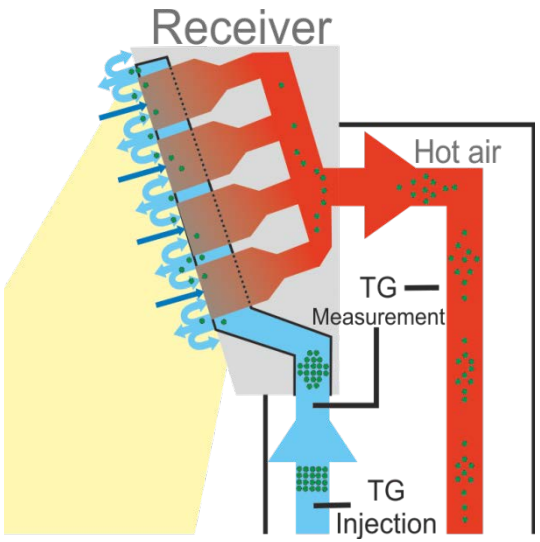
$$ARR = \frac{c_{after}}{c_{before}}$$



Dynamic measurement

1 point of measurement

ARR from curve

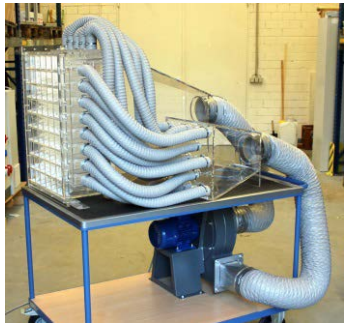


Pulsed measurement

1 point of measurement

ARR impossible

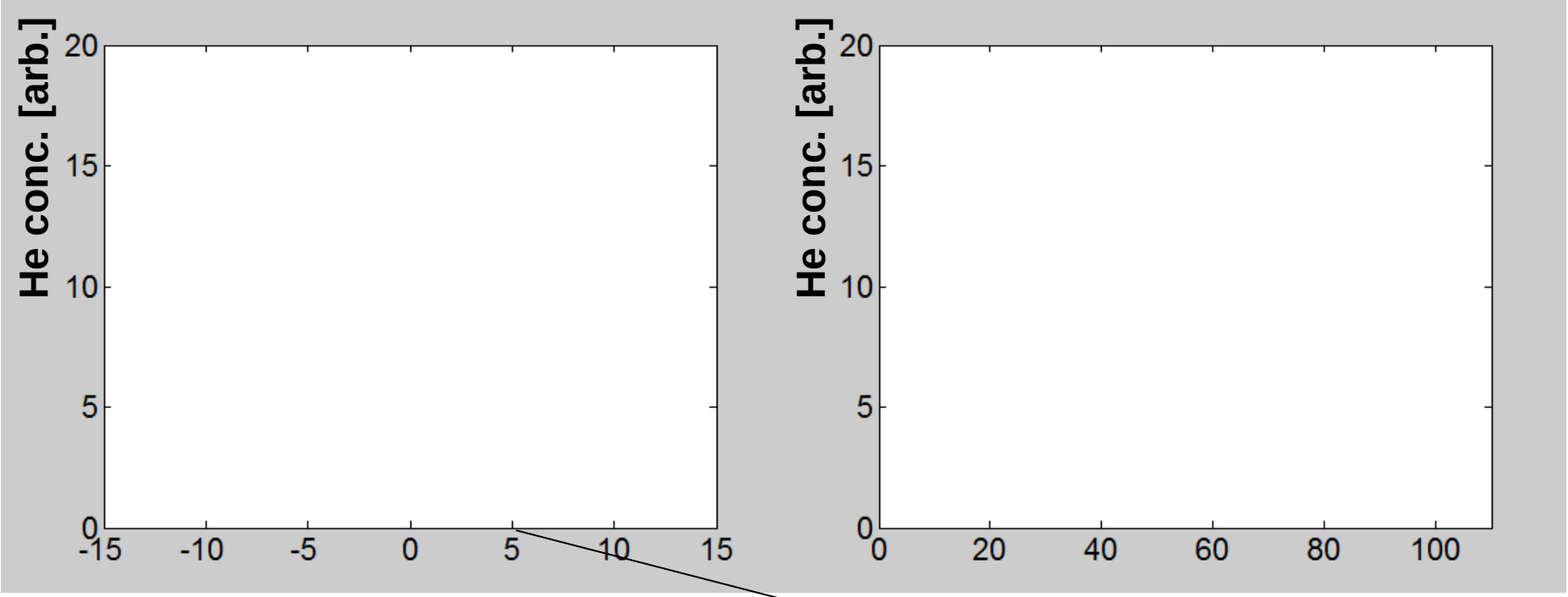
Development phases



Testing environment	Small experiment Jülich	Dish Almeria	Solar Tower Jülich
Testing phase	Start small, cold	small, hot	Goal large, hot

Method of measurement – pulsed measurement

Measurement



Distance from injection[arb.]

measurement

Time [arb.]